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TABLE OF CONTENTS

TITLE	AUTHOR	PAGE
COMPILATION OF GEOCHRONOLOGIC DATA FOR THE YELLOWKNIFE GREENSTONE BELT (85J/8, 85J/9) AND VICINITY, DISTRICT OF MACKENZIE, NWT	R.M. Easton	1
THE BIG SPRUCE LAKE ALKALINE COMPLEX,PROGRESS REPORT	P.W. Cavell and D.G.W. Smith	21
SEDIMENTOLOGY AND STRATIGRAPHY OF A MIDDLE-UPPER DEVONIAN SEQUENCE IN THE POWELL CREEK AREA, NWT	O.A. Dixon	29
ESKERS IN THE REDROCK LAKE REGION, NWT: A POSSIBLE PROSPECTING TOOL	Denis A. St-Onge	39
STRUCTURE AND METAMORPHISM OF THE KESKARRAH BAY AREA POINT LAKE, NWT - SECOND PRELIMINARY REPORT	V.A. Jackson	47
FACIES ANALYSIS OF A MIDDLE DEVONIAN SEQUENCE IN THE MOUNTAIN RIVER-GAYNA RIVER	Iain Muir and Owen Dixon	55
GEOLOGIE DU QUATERNAIRE DE LA REGION DE LA RIVIERE KENNARCTIC, DISTRICT DU MACKENZIE, TNO	Helene C. Bruneau	63
MARTIN FORBISHER'S "GOLD MINES" ON KODLUNARN ISLAND AND ADJACENT BAFFIN ISLAND, FROBISHER BAY, NWT	D.D. Hogarth	69
GEOLOGY OF A VOLCANIC PILE AT CLAN LAKE, NWT	E. Hurdle	79
SUMMARY OF WORK DONE ON THE GEOLOGY OF THE ADAM AND KAMUT LAKE MAP AREAS (86K/8, 86K/9), NWT	W.R. Van Schmus and S. Bowring	91
MISSISSIPPI VALLEY TYPE LEAD-ZINC DISTRICTS OF NORTHERN CANADA	Walter A. Gibbins	95
A BIBLIOGRAPHY OF REFERENCES TO THE SLAVE STRUCTURAL PROVINCE WITH EMPHASIS ON THE YELLOWKNIFE REGION	compiled by H. Helmstaedt	107
GEOLOGY OF THE THOR LAKE BERYLLIUM DEPOSITS: AN UPDATE	D.L. Trueman, J.C. Pedersen, L. de St. Jorre	115
GOLD DEPOSITS OF THE NWT: CLASSES, STYLES, GENESIS, EXPLORATION METHODS,AND SUCCESS PROBABILITIES	W.A. Padgham	121

INTRODUCTION

This first volume of contributions to the geology of the NWT comprises papers written by personnel of the Northern Affairs Program (NAP) Geology Division in Yellowknife, program-funded university researchers, officers of the Geological Survey of Canada and industry explorationists. Such papers were previously included with the NAP's annual Mineral Industry Reports, but the volume of material currently being generated justifies a separate publication. Many of the articles in this volume were submitted to fulfill program-funded contracts, but we would like to take this opportunity to encourage submissions for Volume 2 from other sources, especially from industry geologists whose experience exploring for mineral deposits in the NWT would make their contributions particularly valuable. Submissions in either official language should be forwarded to W.A. Padgham, Chief Geologist, Northern Affairs Program, Box 1500, Yellowknife, NWT, X1A 2R3.

Ce premier volume des contributions à la géologie des TNO comprend des études preparées par le personnel du Programme des Affaires du Nord (PAN) en poste à Yellowknife, des chercheurs Universitaires subventionnés par le PAN, les membres de la Commission Géologique du Canada de même que des géologues de l'industrie privée. Ces études étaient auparavant incluses dans les Rapports de l'Industrie du Minerai publiés annuellement par le PAN. Cependant, le volume de matériel presentement généré justifie une publication séparée. Nous voulons profiter de cette occasion pour encourager tous les chercheurs, spécialement les géologues de l'industrie privée, à soumettre des articles de façon à complèter un deuxième volume. Les articles peuvent être soumis dans l'une ou l'autre des langues officielles à W.A. Padgham, Géologue en Chef, Programme des Affaires du Nord, C.P. 1500, Yellowknife, TNO, X1A-2R3.

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COMPILATION OF GEOCHRONOLOGIC DATA FOR THE YELLOWKNIFE GREENSTONE BELT (85J/8, 85J/9) AND VICINITY, DISTRICT OF MACKENZIE, N.W.T.

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INTRODUCTION

This paper summarizes the last 20 years of geochronologic research in the Yellowknife area. In doing so, it provides a tabulation of previous data corrected to current IUGS constants (Steiger and Jager, 1977), thereby making a large body of information both accessible and consistent. A brief analysis of the tabulated data is also presented to outline areas where our knowledge of the geochronology of the Yellowknife area is deficient, and to direct future geochronologic research. This paper assumes a familiarity with the basics of isotopic age dating techniques. Reviews of these methods may be found in Stockwell (1982), York and Farquahar (1972), and Jager and Hunziker (1979).

RESULTS

Data are listed in Table 1 and plotted on Figures 1 and 2 for N.T.S. sheets 85J/8 (Yellowknife) and 85J/9 (Prosperous Lake) respectively. Data for the Yellowknife region (N.T.S. 85I, 85J, 85K/E, 85N/S, 85O/S, and 85P/S) are tabulated in Table 2 and plotted on Figure 3. Symbols for the tables and figures are given in Table 3. Figure 4 summarizes the Yellowknife area data (excepting diabase dykes) as a histogram.

PRECAUTIONARY NOTES

The tables of age data for the Yellowknife Region (Tables 1 and 2)* should be used with a degree of caution. First, the data have accumulated over a period of years and is of variable quality. No effort has been made to distinguish between 'high' or 'poor' quality data. In all cases, the original reference(s) should be consulted prior to drawing any major conclusions on the basis of any individual age(s) from the table. Secondly, different isotopic systems and analyzed materials respond differently to the conditions present during initial crystallization of a rock, and any subsequent modifications that that rock may have undergone. For example, it has long been known that hornblende has a higher blocking temperature for Ar than does biotite, and hence, K-Ar hornblende ages are commonly higher than K-Ar biotite ages for the same unit. In addition, it would not necessarily be expected for U-Pb and Rb-Sr isotopic systems to yield the same age from the same unit, as both systems record closure of different isotopic systems in different materials and under different P and T conditions. Again, the original reference should be consulted prior to drawing any major conclusions from the data in Tables 1 and 2. Thirdly, local geologic features that may be significant in the interpretation of the isotopic age data listed in Tables 1 and 2 are not always fully explained because of space consideration. Again, the original source should be consulted.

DISCUSSION

CORRESPONDENCE OF ISOTOPIC AGE SYSTEMS

As illustrated in Figure 4, there is a cluster of U-Pb, Rb-Sr, and K-Ar muscovite and hornblende ages between 2500 and 2575 Ma, but U-Pb and Pb-Pb ages extend back to 2700 Ma and K-Ar biotite ages cluster mainly between 2350 and 2475 Ma. The correspondence of the three isotopic systems in the period 2500 to 2575 Ma is significant, especially when interpreting radiometric ages in the region. Two possible interpretations are considered: I) All of the isotopic systems closed at approximately the same time, hence the agreement between the ages. In this case, the ages would be ages of emplacement; II) Most ages are reset ages, in this case all isotopic systems were totally or partly reset to the interval 2500-2575 Ma. The older U-Pb and Pb-Pb ages approximate the age of volcanism and sedimentation, and possibly plutonism in the Yellowknife region.

The second interpretation is favoured for the following reasons: a) The zircon data from the Yellowknife area mainly yield concordia plots with data points far from concordia, concordia ages highly dependent on one data point, or are simply discordant $^{207}Pb/^{206}Pb$ minimum ages. Recent geochronology in the Slave Province has not demonstrated a close correspondence between zircon ages and Rb-Sr and K-Ar muscovite and hornblende ages (e.g. Frith and Loveridge, 1982; Figure 6). b) As shown in Figure 5, all units dated by Rb-Sr methods, except the Prosperous Lake Granitic mineral isochron, show a correlation between Rb or Sr or both and model age. Such a correlation is common in reset isotopic systems (Bickford and Mose, 1975; Page, 1978; Easton, 1982). Hence, the Rb-Sr ages in the region may not be a reliable indicator of crystallization ages. In fact, Green and Baadsgaard (1971) recognized that the Rb-Sr age on the Ross Lake granite was probably affected by K-metasomatism. Cumming and Tsong (1975) suggested that the Prosperous Lake Granite was older than ca. 2500 Ma because it was cut by Dogrib dykes dated at 2635+80 Ma (Gates and Hurley, 1973). c) As shown in Figure 6, K-Ar muscovite and hornblende and Rb-Sr whole-rock ages elsewhere in the Slave Province are generally about 100 Ma younger than corresponding zircon ages from the same unit, e.g. Nose Lake-Beechey Lake area (Frith and Loveridge, 1982) and Point Lake (Figure 6). Similar relationships occur in the Bear Province (Figure 6), where regional resetting of K-Ar and Rb-Sr isotopic systems is better documented (Easton, 1982). The same is true in the Superior Province, where high-precision zircon ages obtained by Tom Krogh and colleagues at the Royal Ontario Museum are regularly 100 Ma older than corresponding Rb-Sr, and K-Ar muscovite and hornblende ages obtained from the same unit (unpublished data, Ontario Geological Survey). Therefore, to support interpretation I, it must be demonstrated that the three isotopic systems do indeed represent emplacement ages.

As shown in Figure 6, across the Slave Province, K-Ar muscovite and hornblende and Rb-Sr whole rock ages are commonly 100 Ma younger than corresponding zircon ages. A similar trend is observed in the Superior Province in Ontario, and in the Bear Province. This is probably not a unique phenomenon, and may be more characteristic of shield regions in general. The significance of this clustering of K-Ar and Rb-Sr ages in the range of 2500 - 2575 Ma is not

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* *Because they are lengthy, Tables 1 and 2 are included as appendices at the end of this paper.*

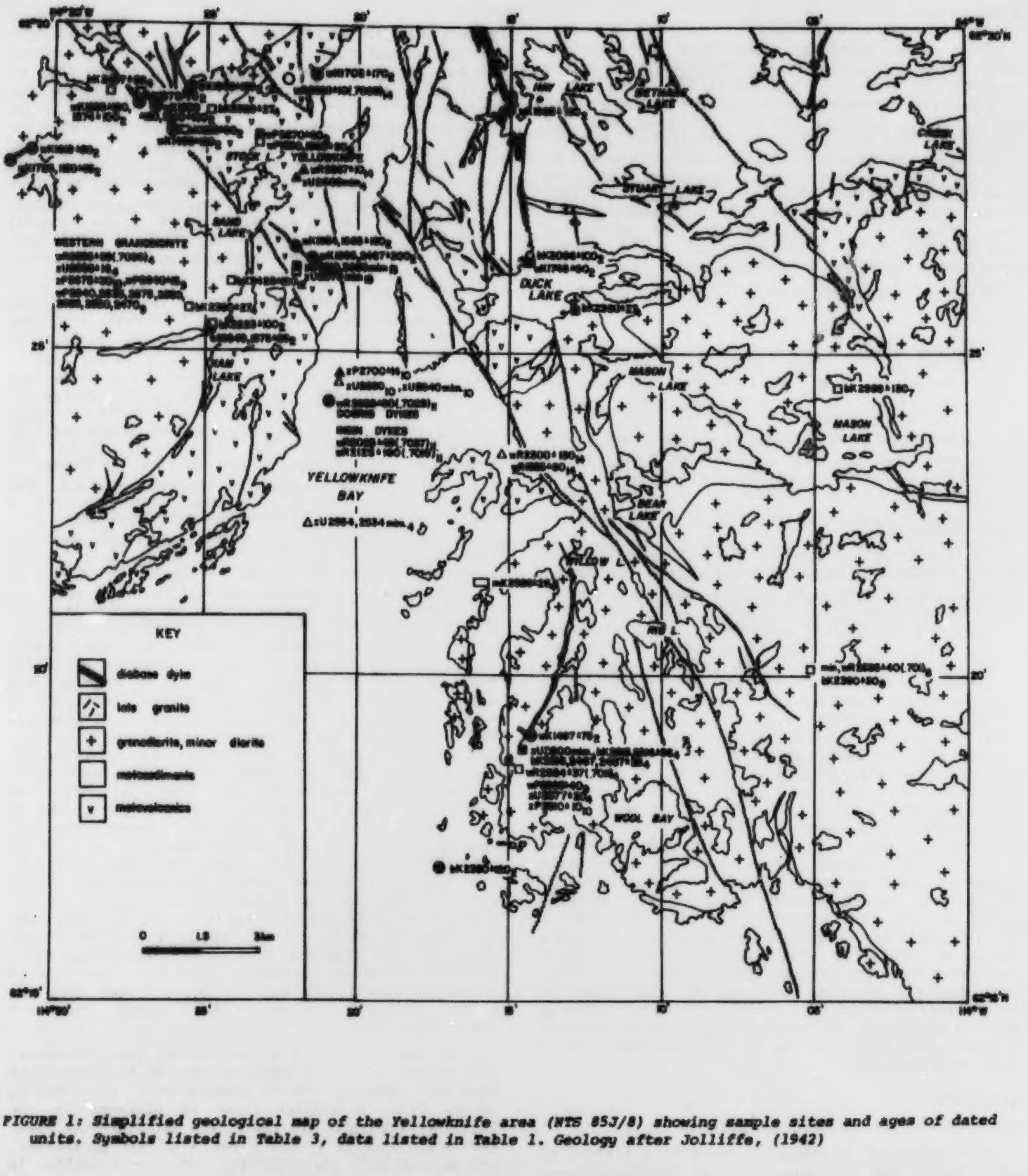

FIGURE 1: Simplified geological map of the Yellowknife area (NTS 85J/8) showing sample sites and ages of dated units. Symbols listed in Table 3, data listed in Table 1. Geology after Jolliffe, (1942)

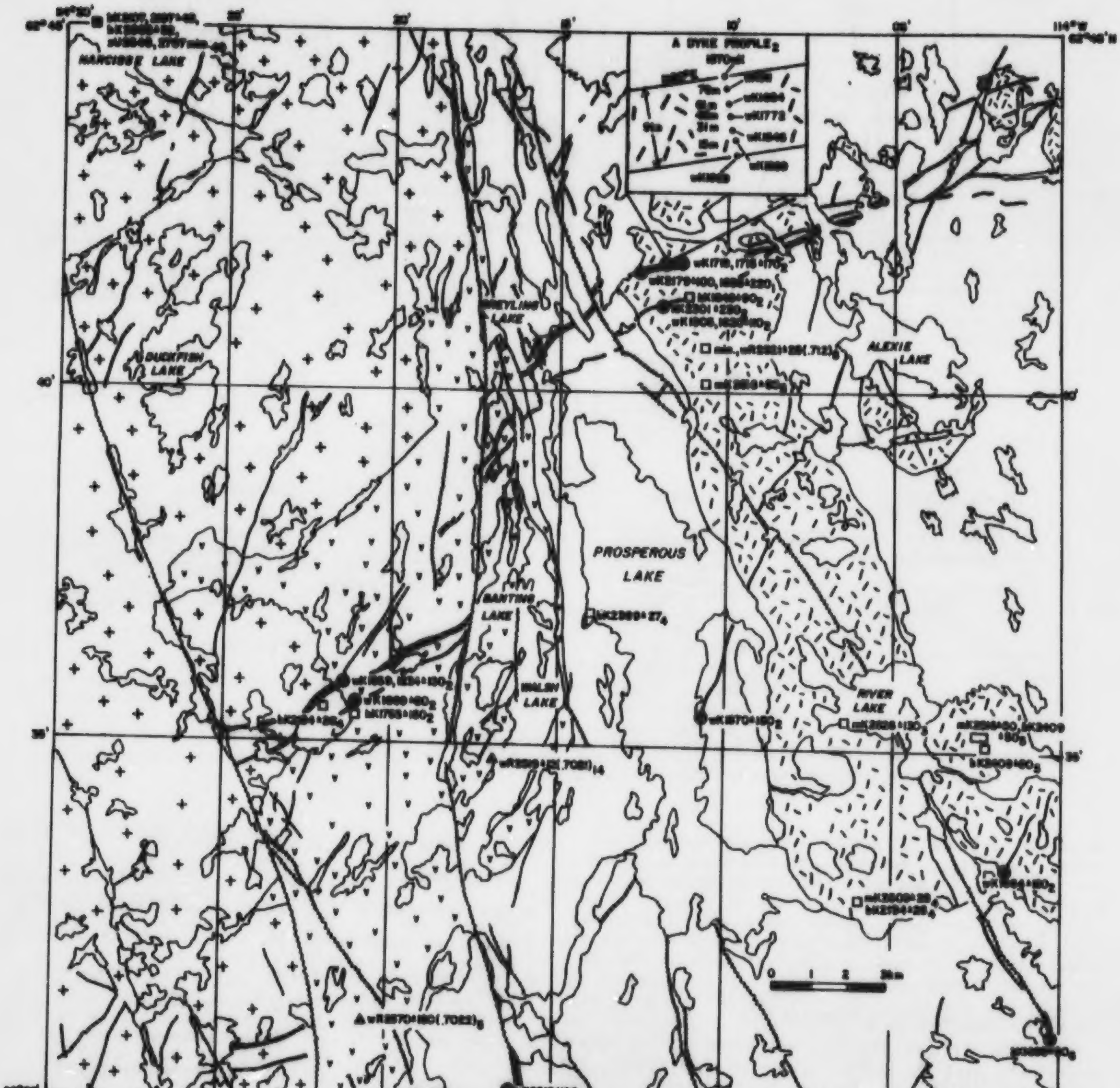

FIGURE 2: *Simplified geological map of the Prosperous Lake area (NTS 85J/9) showing sample sites and ages of dated units. Symbols listed in Table 3, data listed in Table 1. Lithologic units as in Figure 1. Geology after Jolliffe, (1945)*

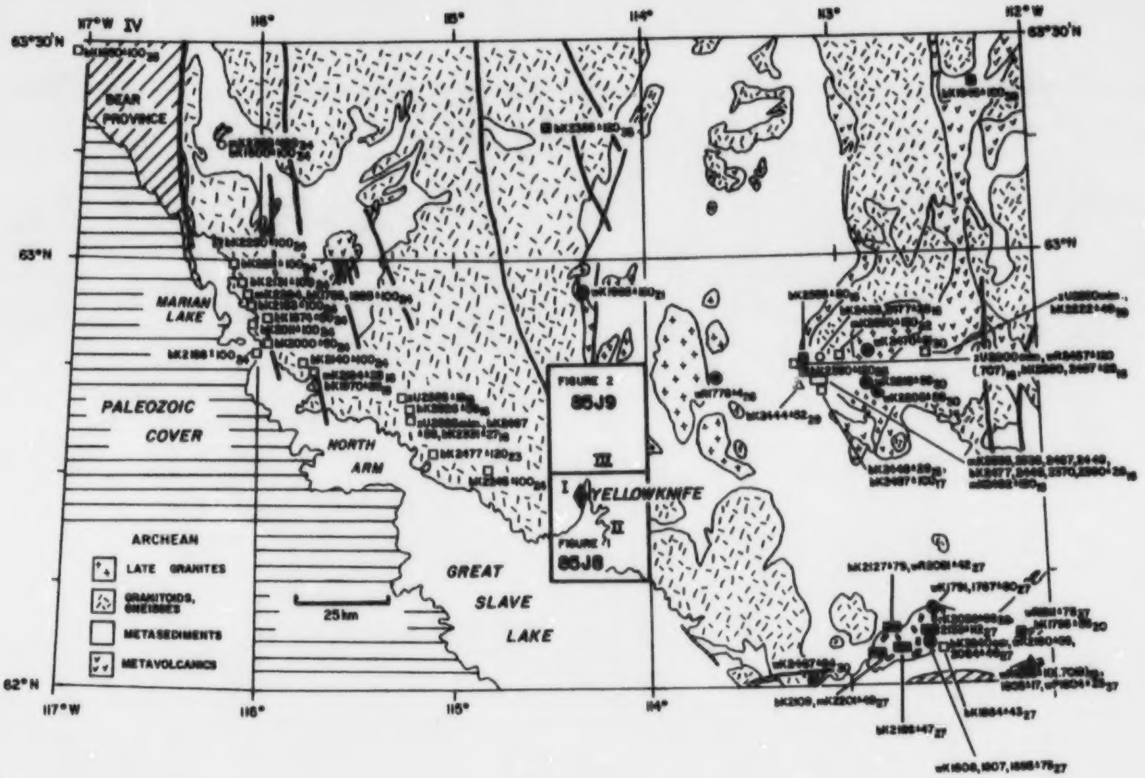

FIGURE 3: Sample sites and ages of dated units in the Yellowknife region. Symbols are listed in Table 3, data in Table 2. Geology after McGlynn (1977). Roman numerals: 1- Yellowknife volcanics; 11- Southeast Granodiorite; 111- Prosperous Lake Granite; 1V- Basler Lake Granite.

known -- was it a period of cooling and low-temperature fluid movement that gradually ceased about 2500 Ma or was it a period of resetting that occurred about 100 Ma after volcanism and plutonism in the greenstone belts of the Slave Province? Until this problem is resolved, care is required when interpreting Rb-Sr ages in the Bear-Slave region as ages of emplacement.

AGE OF THE YELLOWKNIFE SUPERGROUP

The age of the Yellowknife Supergroup in the Yellowknife area is poorly known, the best estimates being the 2600 Ma concordia age on zircons from Yellowknife Supergroup turbidites reported by Thorpe (1971) and the 2670 Ma composite concordia plot of zircons from Yellowknife Supergroup volcanics and sediments from across the Slave Province (Frith and Loveridge, 1982). These ages are roughly 100 Ma older than Rb-Sr whole-rock isochron ages on Yellowknife Supergroup volcanic rocks (Table 1, Figures 4 and 6). As shown in Figure 5, Yellowknife Supergroup volcanic samples used in the isochron plot reported by Green et al. (1968) show a correlation between Rb and Sr and model age, a probable indicator of some open-system behaviour following extrusion of the Yellowknife volcanics.

TABLE 3: SYMBOLS AND ABBREVIATIONS

	DATING METHOD		ROCK TYPE
K	potassium-argon	□	granodiorite, granite
R	rubidium-strontium	◩	diorite
U	uranium-lead, includes $^{207}Pb/^{206}Pb$ minimum ages	■	gneiss, migmatite
		▲	volcanics
P	lead-lead	△	sediments
		○	metamorphic rocks
	MINERALS	▭	pegmatite
min.	mineral	▬	alkaline intrusions
b	biotite	●	diabase dyke
m	muscovite		
h	hornblende		**ABBREVIATIONS**
r	riebeckite	mim	minimum
z	zircon	w	whole-rock
		dis	discordant
		ear	excess argon

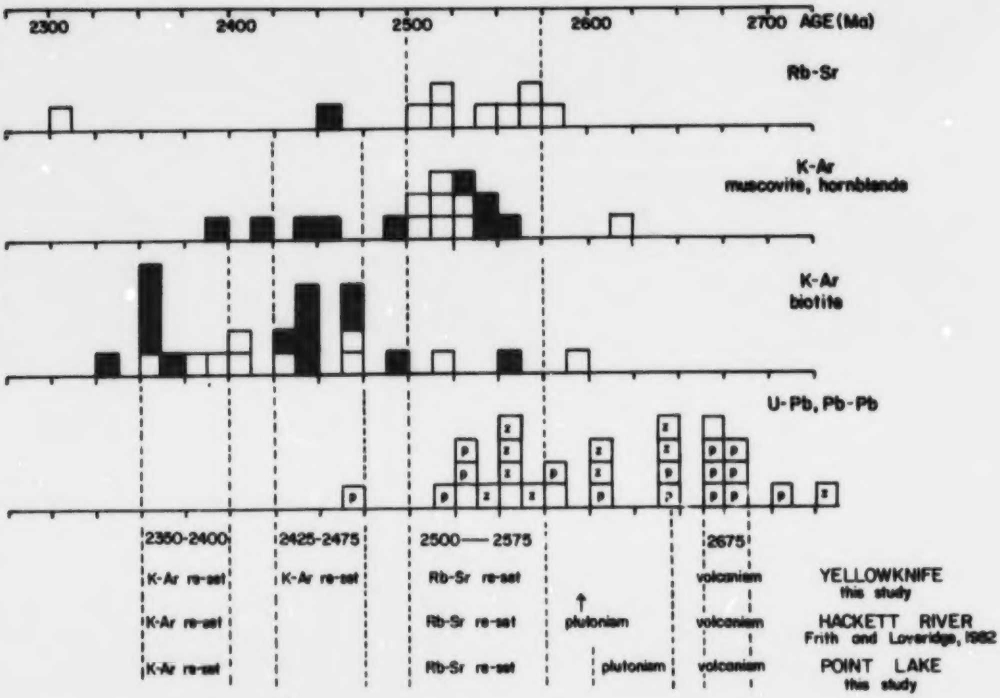

FIGURE 4: Histograms of radiometric ages greater than 2300 Ma for the Yellowknife region exclusive of diabase dikes. Rb-Sr and K-Ar plots: open squares = data from NTS 85J8 and 85J/9; filled squares = data from area shown in Figure 3. U-Pb plot: Z = Pb/Pb, minimum ages from zircons; no symbol = concordia age on zircon; P = Pb/Pb ages based on whole-rock (Cumming and Tsong, 1975) or zircons (Thorpe, 1971). A possible interpretation of the geological significance of the age clusters is given at the bottom of the figure. Lambert and others (1984) have reported a four-point Nd-Sm isochron for the Kam and Banting Formation volcanic rocks of 2650±26 Ma, in rough agreement with the U-Pb and Pb-Pb ages of the Yellowknife volcanic rocks.

AGE OF THE WESTERN GRANODIORITE

The western granodiorite is due west of Yellowknife (Figure 1). A very discordant plot of zircon data (Green and Baadsgaard, 1971) yields the same age as the Rb-Sr isochron for the Western Grandodiorite, namely 2555 Ma (Green et al., 1968). As noted by Thorpe (1971) and Green and Baadsgaard (1971), the concordia plot is controlled by a single point from the Fort Rae highway; the other points could be on a chord intersecting the curve at 2680 Ma, in close agreement with the 2675+40 Ma Pb-Pb age of Thorpe and the ca. 2640 Ma Pb-Pb age of Cumming and Tsong (1975). Hence, the age of the Western Granodiorite could be close to the age of extrusion of the Yellowknife volcanic rocks.

AGE OF THE SOUTHEASTERN GRANODIORITE

The southeastern granodiorite is southeast of Yellowknife (Figure 1) and consists of a diorite phase and a granodiorite phase (Joliffe, 1942; Easton et al., 1982). The diorite phase consists of diorite probably related to an early phase of the SE Granodiorite (Easton et al., 1982; unit 18c) and diorite consisting of partly assimilated volcanic material (Easton et al., 1982; unit 18f). The concordia plot and isochron of Green and Baadsgaard (1971) were based mainly on diorite samples, however, the location given by Green and Baadsgaard contains both diorite types in close proximity. Hence, it is not certain which diorite was dated - the dated samples may have included partly assimilated volcanic material. The minimum age of the diorite phase of the SE Granodiorite is a 2600 Pb-Pb minimum age from a zircon, and a 2613+57 Ma K-Ar hornblende age (Green and Baadsgaard, 1971). The minimum age of the granodiorite phase is a 2526+28 Ma K-Ar muscovite age (Green and Baadsgaard, 1971) from a pegmatite cutting the granodiorite and a 2535+40 Ma Rb-Sr mineral and whole-rock age reported by Van Breeman (1965). Further work is needed to better determine the age of the SE Granodiorite, the age relations between the diorite and granodiorite phases, and the relative age of the Western and SE Granodiorites.

AGE OF THE PROSPEROUS LAKE GRANITE

The Prosperous Lake Granite is a post-orogenic two-mica granite intruded into Yellowknife Supergroup sedimentary rocks NW of Yellowknife (Figure 2). As illustrated in Figure 5, the Prosperous Lake Granite is the only unit dated by Rb-Sr methods in the Yellowknife area that does not show a correlation between

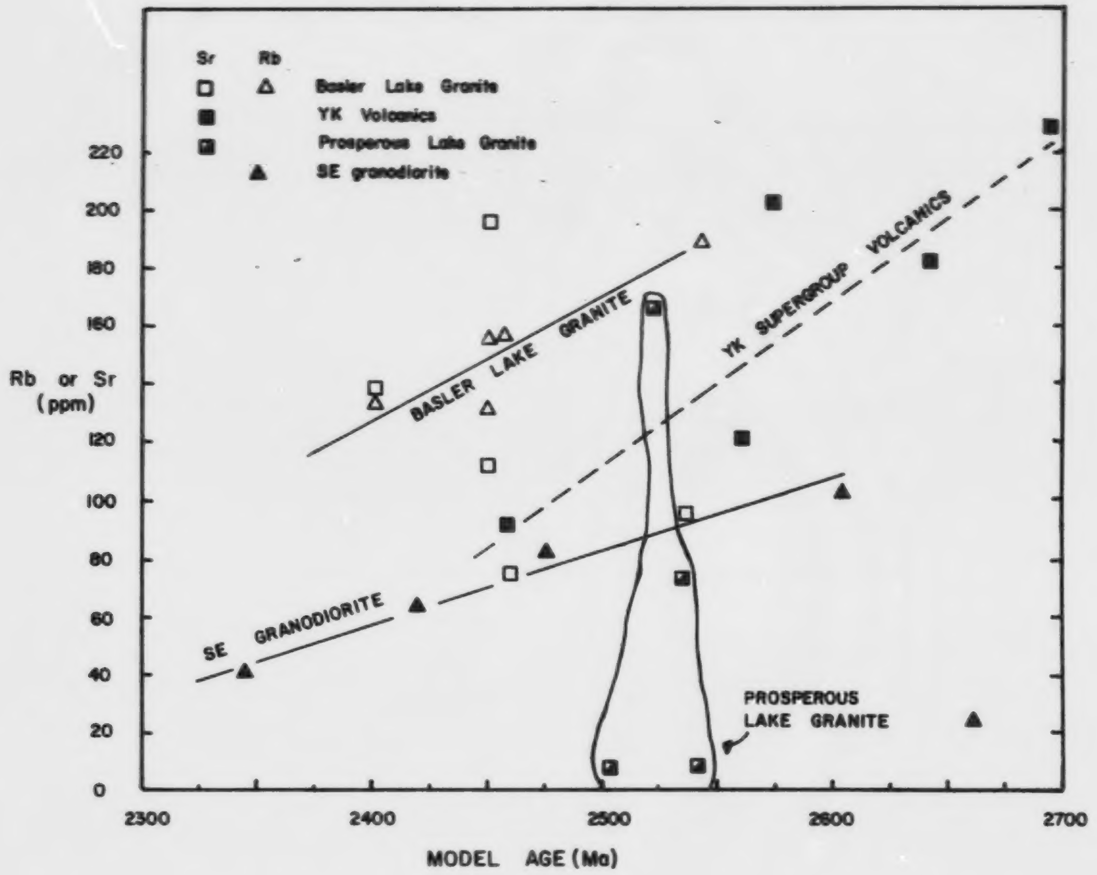

FIGURE 5: Plot of Rb and Sr versus model age for selected units in the Yellowknife area (units shown by Roman numerals in Figure 3). The Basler Lake Granite yields a whole-rock Rb-Sr age of 2510 ± 106 Ma (Wanless and Loveridge,1972), but has been affected by an early Proterozoic event resulting in a mineral isochron age of 1932 ± 24 Ma((Wanless and Loveridge, 1972). Note the correspondence between Rb and model age for lower model ages. This is common in reset Sr isotopic systems (Bickford and Mose,1975; Page, 1976; Easton, 1982, 1983). The Southeast Granodiorite shows a correlation between Rb and Sr (not shown) and model age, as do the Yellowknife Supergroup volcanic rocks for both Rb (not shown) and Sr. The Prosperous Lake Granite is the only pluton in the Yellowknife region dated by Rb-Sr whole-rock methods not to show a correlation between Rb (not shown) or Sr and model age, however, this is a mineral isochron, hence, it probably approximates the time of Rb-Sr closure on hand specimen and mineral scale in the region. The other Rb-Sr whole-rock ages are probably reset, as discussed in detail in the text. Prosperous Lake Granite, data of Green and Baadsgaard (1968), assumed Sr initial = 0.710; Southeast Granodiorite, data of Green and Baadsgaard (1971), assumed Sr initial = 0.702; Basler Lake Granite, data of Wanless and Loveridge (1972), assumed Sr original = 0.701.

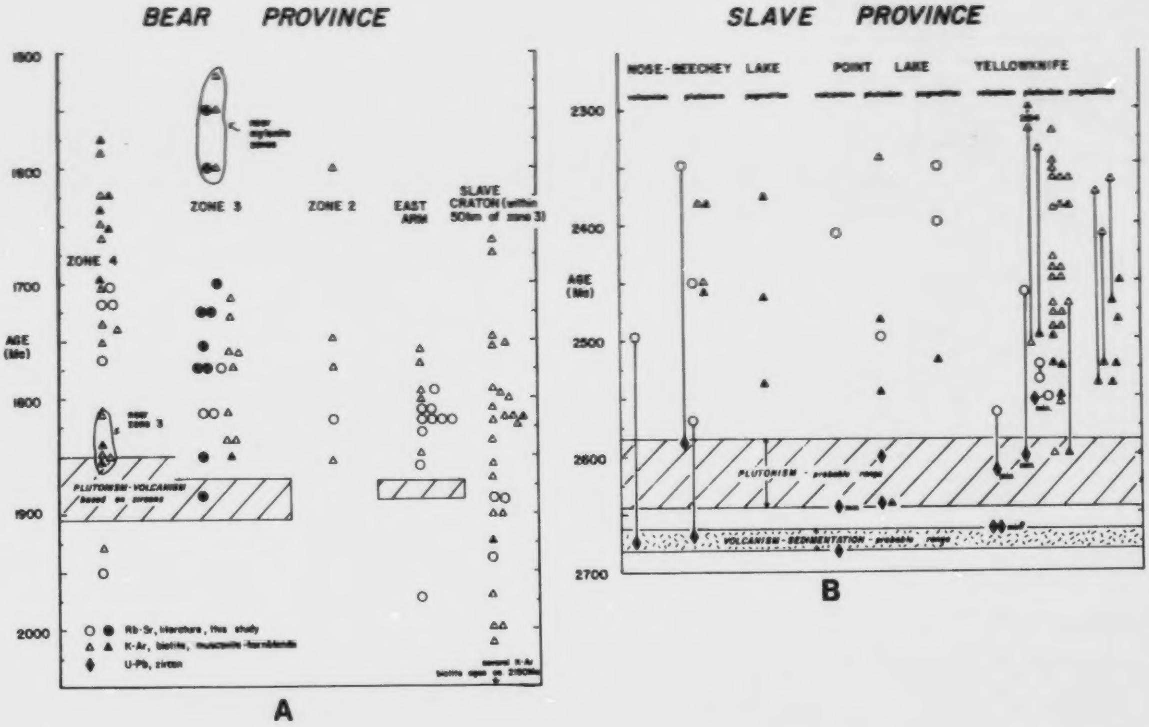

FIGURE 6: Comparison of K-Ar, Rb-Sr, and U-Pb ages in the Slave Province with those from the Bear Province. A) In the Bear Province, K-Ar and Rb-Sr ages are generally 100 Ma younger than the U-Pb zircon ages from the same unit (Easton, 1983). B) In the Slave Province, K-Ar and Rb-Sr ages are also generally 100 Ma younger than U-Pb zircon ages from the same unit. Vertical lines in Figure 6B indicate Rb-Sr/U-Pb or K-Ar muscovite/ K-Ar biotite ages from the same unit. Data for Nose Lake-Beechey Lake from Frith and Loveridge (1982); for Point Lake, Wanless and Loveridge (1978), Grogh and Gibbons (1978); and for Yellowknife from Tables 1 and 2. Data for the Bear Province from Easton (1982)

Rb or Sr or model age. However, as the 2521±25 Ma Rb-Sr age obtained by Green et al (1968) for this unit is a mineral isochron, this age pobably reflects the regional apparent closure of Rb-Sr systems at about 2525 Ma. This is also the upper age of K-Ar muscovite ages in the region, and the mean Rb-Sr age for the isochrons of the Yellowknife area is 2545 Ma. Hence, 2525 Ma should be regarded as a minimum age for this unit.

AGE OF DIABASE DYKE SWARMS

The age of the Dogrib Dyke (MacKenzie Set I) swarm is fixed at 2635±80 Ma by a Rb-Sr isochron based on whole-rock samples from several widely scatted localities (Gates annd Hurley, 1973). Further resolution of this age is important, because it would place a lower limit for the intrusion of the Western, SE and Prosperous Granodiorites. Although not statistically different from the Rb-Sr isochron age on these plutons, the dyke age is apparently older than other Rb-Sr whole-rock isochron ages in the region (Figure 4) and may also be important in placing constraints on the timing and resetting of Rb-Sr isotopic systems in the region.

The conjugate Indin dyke swarm (MacKenzie Set II and IV) has a Rb-Sr age of 2049±80 Ma (Gates and Hurley, 1973), similar to mean K-Ar age of the Blachford Complex (2050-2100 Ma; Wanless et al., 1979), the Duck Lake Sill (ca. 2050 Ma; Leech, 1966) and the Big Spruce Alkaline Complex (2066±40 Ma; Martineau and Lambert, 1974), and may be related to an early stage of rifting (pre-Akaitcho Group) associated with the formation of Wopmay Orogen.

Other diabase dyke ages in the Yellowknife region are based mainly on K-Ar whole-rock determinations and are highly variable and considered to be generally unreliable. In general, whole-rock ages in the Yellowknife area appear to be generally lower near faults, possibly due to local movement along faults in the area in the early Proterozoic (Figure 7).

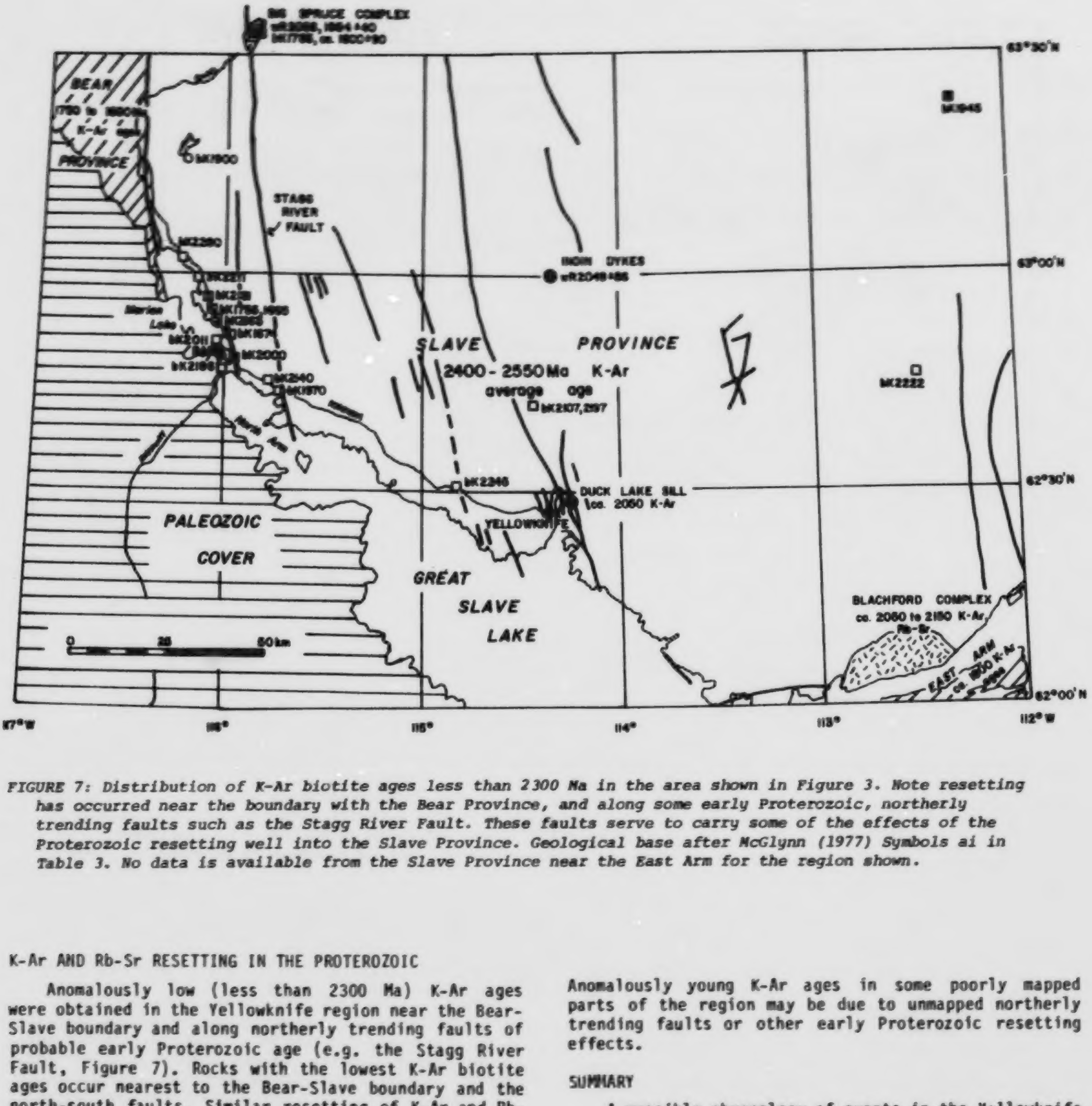

FIGURE 7: Distribution of K-Ar biotite ages less than 2300 Ma in the area shown in Figure 3. Note resetting has occurred near the boundary with the Bear Province, and along some early Proterozoic, northerly trending faults such as the Stagg River Fault. These faults serve to carry some of the effects of the Proterozoic resetting well into the Slave Province. Geological base after McGlynn (1977) Symbols ai in Table 3. No data is available from the Slave Province near the East Arm for the region shown.

K-Ar AND Rb-Sr RESETTING IN THE PROTEROZOIC

Anomalously low (less than 2300 Ma) K-Ar ages were obtained in the Yellowknife region near the Bear-Slave boundary and along northerly trending faults of probable early Proterozoic age (e.g. the Stagg River Fault, Figure 7). Rocks with the lowest K-Ar biotite ages occur nearest to the Bear-Slave boundary and the north-south faults. Similar resetting of K-Ar and Rb-Sr isotopic systems has been described elsewhere adjacent to the Bear-Slave boundary (Easton, 1982, 1983). This resetting near the Bear-Slave boundary and along the northerly trending faults should be taken into consideration when sampling for geochronologic studies in the Yellowknife region. Anomalously young K-Ar ages in some poorly mapped parts of the region may be due to unmapped northerly trending faults or other early Proterozoic resetting effects.

SUMMARY

A possible chronology of events in the Yellowknife region is outlined in Table 4. The chronology of the Yellowknife area is not well known on the basis of current data, and should be studied further. This study shows that considerable care should be taken in the Yellowknife-Slave region in sampling and in the interpretation of Rb-Sr results.

TABLE 4: GEOLOGICAL HISTORY OF THE YELLOWKNIFE REGION

UNIT OR EVENT	AGE
basement	2700 to 3200 Ma[1]
Yellowknife Supergroup volcanism, sedimentation	ca2660 to 2680 Ma
plutonism and regional metamorphism	ca2620 to 2660 Ma[2]
pegmatite emplacement	ca2600 to 2640 Ma
Dogrib dyke emplacement	2635 ± 80 Ma
K-Ar muscovite and hornblende and most Rb-Sr isotopic systems close	2500 to 2550 Ma[3]
most K-Ar biotite isotopic systems close	2425 to 2475 Ma
final K-Ar biotite closure	2350 to 2400 Ma
N trending faults, Indin dike swarm emplaced	ca2050 Ma
main Proterozoic resetting of K-Ar and Rb-Sr isotopic systems	ca1900 Ma[4]

[1] upper limit from Nikic et al., 1980

[2] poorly known, in Superior Province most syn-tectonic plutonism occurs within 50 Ma of end of volcanism (data of Krogh, ROM).

[3] spread poorly defined, nature of resetting event unknown

[4] based on age of plutonism in Wopmay Orogen, produces K-Ar and Rb-Sr ages ranging from 1700 to 1850 Ma

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TABLE 1: TABULATION OF PUBLISHED AGE DATA FOR THE YELLOWKNIFE AREA (NTS 85J/8, 85J/9). ABBREVIATIONS ARE LISTED IN TABLE 3 AND AGES ARE PLOTTED IN FIGURES 1 AND 2.

REF#[1]	AGE	METHOD	ROCK TYPE	COMMENT	SAMPLE NUMBER	LOCATION	NTS	SOURCE
1	2179±120	wK	diabase	Dogrib Dyke	GSC 63-54	62°49'N 114°13'W	85J/9	Wanless et al., 1965
1	1836±220	wK	diabase	re-run of GSC 63-54 considered more reliable by GSC	GSC 70-69	62°49'N 114°13'W	85J/9	Wanless et al., 1965
2	2086±100	bK	hornfels	Duck Lake Sill	AK 497	60°26'N 114°14'W	85J/8	Leech, 1966
2	1748±90	wK	diabase	Duck Lake Sill	AK 464	62°26'N 114°14'W	85J/8	Leech, 1966
2	1925±100	wK	diabase	Duck Lake Sill	AK 463	62°28'N 114°15'W	85J/8	Leech, 1966
2	2013±100	wK	diabase	Duck Lake Sill	AK 520	62°30'15"N 114°16'15"W	85J/9	Leech, 1966
2	1497±75	wK	diabase	Duck Lake Sill	AK 524	62°18'45"N 114°14'15"W	85J/8	Leech, 1966
2	2380±120	bK	diabase	Dogrib Dykes	AK 518	62°16'45"N 114°17'30"W	85J/8	Leech, 1966
2	1830±180 124-±100	wK	diabase	Dogrib Dykes	AK 515 AK 536 core	62°29'N 114°26'15"W	85J/8	Leech, 1966
2	1669±80	wK	diabase	Dogrib Dykes	AK 584	62°35'30"N 114°21'W	85J/9	Leech, 1966
2	1659±130 1234±125	wK	diabase	Dogrib Dykes	AK 586 AK 587	62°36'N 114°22'W	85J/9	Leech, 1966
2	1619±80	wK	diabase	Dogrib Dykes	AK 583	62°28'N 114°30'30"W	85J/8	Leech, 1966
2	1723±85 1150±60	wK	diabase	Dogrib Dyke	AK 579 AK 582 core	62°28'N 114°31'W	85J/8	Leech, 1966
2	2301±230	hK	diabase	Dogrib Dyke	AK 261	62°41'N 114°12'W	85J/9	Leech, 1966
2	1753±150	hK	granite	adj. Dogrib Dyke	AK 580	62°35'30"N 114°21'W	85J/9	Leech, 1966
2	1906±110	wK	diabase	Dogrib Dyke	AK 460	62°41'N 114°12'W	85J/9	Leech, 1966
2	1620±100	wK	diabase	Dogrib Dyke	AK 466	62°41'N 114°12'W	85J/9	Leech, 1966
2	1070±125	wK	diabase	Dyke profile, Dogrib Dyke	AK 473 N margin 91 m	62°42'N 114°12'W	85J/9	Leech, 1966
2	912±55	wK	diabase	Dyke profile, Dogrib Dyke	AK 472 76 m	62°42'N 114°12'W	85J/9	Leech, 1966
2	1880±85	wK	diabase	Dyke profile, Dogrib Dyke	AK 471 61 m	62°42'N 114°12'W	85J/9	Leech, 1966

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[1] The reference number is that number shown as subscripts after the ages in Figures 1 to 3.

TABLE 1 CONTINUED

REF#	AGE	METHOD	ROCK TYPE	COMMENT	SAMPLE NUMBER	LOCATION	NTS	SOURCE
2	1772±90	wK	diabase	Dyke profile, Dogrib Dyke	AK 470 46 m	62°42'N 114°12'W	85J/9	Leech, 1966
2	1546±155	wK	diabase	Dyke profile, Dogrib Dyke	AK 469 31 m	62°42'N 14°12'W	85J/9	Leech, 1966
2	1669±165	wK	diabase	Dyke profile, Dogrib Dyke	AK 468 15 m	62°42'N 114°12'W	85J/9	Leech, 1966
2	1929±190	wK	diabase	Dyke profile, Dogrib Dyke	AK 467 0 m S margin	62°42'N 114°12'W	85J/9	Leech, 1966
2	1846±90	bK	granite	adj. Dogrib Dyke	AK 446	62°41'N 114°11'W	85J/9	Leech, 1966
2	1703±170	wK	diabase	Indin Dyke 300°-315° trend	AK 590	62°29'30"N 114°21'W	85J/8	Leech, 1966
2	1575±75	bK	granite	adj. to Indin Dyke	AK 531	62°29'N 114°26'30"W	85J/8	Leech, 1966
2	1551±80	wK	diabase	Indin Dyke 300°-315° trend	AK 592	62°30'N 114°20'W	85J/9	Leech, 1966
2	1835+180 1274±100	wK	diabase	Indin Dyke 300°-315° trend	AK 523 AK 537 core	62°29'N 114°28'W	85J/8	Leech, 1966
2	1215+90 1466±120	hK wK	granite diabase	Indin dyke 300°-315° trend	AK 577 AK 576	62°28'30"N 114°26'W	85J/8	Leech, 1966
2	1634+160 1555±155	wK	diabase	Indin Dyke 300°-315° trend	AK 574 AK 575 core	62°27'N 114°22'W	85J/8	Leech, 1966
2	1995±200	wK	diabase	Indin Dyke underground	AK 585	62°27'N 114°25'W	85J/8	Leech, 1966
2	2487±250	wK	diabase	Indin Dyke underground (low K)	AK 589	62°27'N 114°25'W	85J/8	Leech, 1966
2	1649+85 1875±80	wK	diabase	Indin Dyke 000°-030° trend	AK 465 AK 439 core	62°25'20"N 114°25'W	85J/8	Leech, 1966
2	1718+170 1718±170	wK	diabase	Indin Dyke 000°-030° trend	AK 474	62°42'N 114°11'30"W	85J/9	Leech, 1966
2	1570±150	wK	diabase	Indin Dyke 000°-030° trend	AK 595	62°35'30"N 114°10'20"W	85J/9	Leech, 1966
2	1684±160	wK	diabase	Indin Dyke 000°-030° trend	AK 527	62°33'30"N 114°02'W	85J/9	Leech, 1966
2	1965±205	wK	diabase	Indin Dyke 000°-030° trend	AK 525	62°29'N 114°25'25"W	85J/8	Leech, 1966
3	2530±130	wK	quartz monzonite		GSC 60-49	62°35'25"N 114°06'25"W	85J/9	Lowdon, 1961

TABLE 1 CONTINUED

REF#	AGE	METHOD	ROCK TYPE	COMMENT	SAMPLE NUMBER	LOCATION	NTS	SOURCE
4	2506±28 2194±26	mK bK	granite	Prosperous Lake granitoid	G204	62°33'N 114°06'W	85J/9	Green & Baadsgaard 1971
4	2389±27	bK	granodiorite			62°36'56"N 114°14'12"W	85J/9	Green & Baadsgaard 1971
4	2608 min.	zU	dacite	Yellowknife Sgp. volc. ^{207}Pb/^{206}Pb dis. mim.	G206	62°27'30"N 114°22'35"W	85J/9	Green & Baadsgaard 1971
4	2320±27	bK	granodiorite	Western Granodiorite	G44	62°28'41"N 114°25'04"W	85J/8	Green & Baadsgaard 1971
4	2184±26	bK	quartz diorite	Western Granodiorite	G33	62°35'33"N 114°22'11"W	85J/8	Green & Baadsgaard 1971
4	2555±58	wR	granite	n=6, 0.7035±0.0027		62°32'N 114°25"W scattered localities	85J/8	Green & Baadsgaard 1971
4	2555±16	zU	granitoids	4 pts. concordia ^{207}Pb/^{206}Pb dis. min., 2534, 2525,2500,2451		62°40'N 115°15'W	85J/8	Green & Baadsgaard 1971
4	2554 min.	zU	diorite boulder in conglomerate	Jackson Lake Fm. ^{207}Pb/^{206}Pb dis. mim.	G116	62°22'N 114°22'W	85J/8	Green & Baadsgaard 1971
4	2534 min.	zU	diorite boulder in conglomerate	Jackson Lake Fm. ^{207}Pb/^{206}Pb dis. mim.	F24	62°17'N 114°25'W	85J/8	Green & Baadsgaard 1971
4	2600 min. 2613±57 2467±28	zU hK bK	diorite	Southeast Granodiorite, ^{207}Pb/^{206}Pb dis. mim.	G120	62°18'59"N 114°14'39"W	85J/8	Green & Baadsgaard 1971
4	2577±20	zU concordia	diorite, granodiorite	6 pts., discordant ^{207}Pb/^{206}Pb dis. mim., 2600, 2579, 2569, 2464, 2564, 2549		Scattered Localities	85J/8	Green & Baadsgaard 1971
4	2584±37	wR	granodiorite	n=7, 0.7011±0.0008 dependent on one high point		Scattered Localities	85J/8	Green & Baadsgaard 1971
4	2526±28	mK	pegmatite	SE Granodiorite	G127	62°21'47"N 114°16'34"W	85J/8	Green & Baadsgaard 1971
4	2516±28 2516±56	bK hK	diorite	SE Granodiorite	G124	62°18'56"N 114°14'49"W	85J/8	Green & Baadsgaard 1971
4	2467±28	bK	diorite	SE Granodiorite	G118	62°18'59"N 114°14'36"W	85J/8	Green & Baadsgaard 1971
4	2360±27	bK	diorite	SE Granodiorite	G307	62°25'40"N 114°13'15"W	85J/8	Green & Baadsgaard 1971
4	2497±56	hK	amphibolite xenolith in granodiorite	Western Granodiorite	G55	62°29'18"N 114°28'40"W	85J/8	Green & Baadsgaard 1971
4	2448±28	bK	adamellite	Western Granodiorite	G50	62°28'13"N 114°23'14"W	85J/8	Green & Baadsgaard 1971

TABLE 1 CONTINUED

REF#	AGE	METHOD	ROCK TYPE	COMMENT	SAMPLE NUMBER	LOCATION	NTS	SOURCE
4	2360±27	bK	quartz diorite	Western Granodiorite	G48	62°25'20"N 114°25'45"W	85J/8	Green & Baadsgaard 1971
5	2409±50	bK	granite	Prosperous Lake granitoid	AK 670	62°35'N 114°02'30"W	85J/9	Green et al., 1968
5	2516±50 2409±50	mK bK	pegmatite	Prosperous Lake granitoid	AK 669 AK 668	62°35'N 114°02'30"W	85J/9	Green et al., 1968
5	2516±50	mK	granite	Prosperous Lake granitoid	AK 193	62°40'N 114°11'W	85J/9	Green et al., 1968
5	2521±25	min, wR	granite	Prosperous Lake granitoid, biotite, plagioclase, muscovite, K-feldspar, apatite, 0.712±0.002		62°41'N 114°11'W	85J/9	Green et al., 1968
5	2570±160	wR	andesite, dacite	Yellowknife Sgp. volcanic n=6, 0.7022±0.0023		62°31'N 114°21'W	85J/9	Green et al., 1968
6	1689±95	h,bK	diabase		GSC 67-82	62°31'N 114°00'W	85J/9	Wanless et al., 1970
7	2599±130	bK	granodiorite	SE Granodiorite	GSC 61-66	62°24'25"N 114°03'55"W	85J/8	Lowdon et al., 1963
8	2380±50	bK	granodiorite	SE Granodiorite		62°20'N 114°05'W	85J/8	Van Breeman, 1965
8	2535±40	min, wR	granodiorite	SE Granodiorite (0.701)		62°20'N 114°05'W	85J/8	Van Breeman, 1965
9	2665±40	wP	diorite, granodiorite	n=7, SE Granodiorite		probably 62°18'40"N 114°14'40"W	85J/8	Cumming and Tsong, 1975
9	2670±60	wP	quartz diorite	n=6, Stock Lake	#2	62°28'N 114°23'W	85J/8	Cumming and Tsong, 1975
10	1880±90 1870±90	wP	acidic rock	n=4, wr only n=5, wr, bi, feld. Stock Lake	#1	62°28'N 114°23'W	85J/8	Cumming and Tsong, 1975
10	2640±5	wP	pegmatite	n=8	#6	unknown		Cumming and Tsong, 1975
10	2635±20	min, wP	pegmatite	n=5, wr, zircon apatite, feldspar	#4	unknown		Cumming and Tsong, 1975
10	2575±40	wP		n=4	#3	unknown		Cumming and Tsong, 1975
10	2530±100	wP		n=7	#8	unknown		Cumming and Tsong, 1975
10	2525±50 2520±50	wP min, wP		n=5 n=5, wr, zircon, apatite, feldspar	#5	unknown		Cumming and Tsong, 1975
10	2470±45	wP		n=4	#7	unknown		Cumming and Tsong, 1975
10	2610±10	zP	granodiorite diorite	^{207}Pb/^{204}Pb-^{206}Pb/^{204}Pb isochron, 12 pts. SE Granodiorite		scattered localities	85J/8	Thorpe, 1971, Green & Baadsgaard 1971

TABLE 1 CONTINUED

REF#	AGE	METHOD	ROCK TYPE	COMMENT	SAMPLE NUMBER	LOCATION	NTS	SOURCE
10	2700±14	zP	volcanics, sediments	^{207}Pb/^{204}Pb ^{206}Pb/^{204}Pb isochron		scattered localities	85J/8	Thorpe, 1971, Green & Baadsgaard, 1971
10	2640 min.	zU	greywacke	Yellowknife Supergroup, ^{207}Pb/^{206}Pb dis. min.		unknown	85J/8	Thorpe, 1971 Green & Baadsgaard, 1971
10	2660	zU	greywacke	Yellowknife Supergroup, 2 pts. concordia		unknown	85J/8	Thorpe, 1971 Green & Baadsgaard 1971
11	2128±180	wR	diabase	Indin 300°-315° trend, n=9, 0.7019±0.001		scattered localities 62°25'N 114°20'W	85J/8	Gates & Hurley, 1973
11	2023±45	wR	diabase	Indin 000°-030° trend, n=10 0.7037±0.0004		scattered localities approx. 63°N 114°20'W	85J/8	Gates & Hurley, 1973
11	2049±86	wR	diabase	Indin combined n=19, 0.7030± 0.0006			85J/8	Gates & Hurley, 1973
11	2635±80	wR	diabase	Dogrib Dyke Swarm, n=12, 0.7028±0.0005		scattered localities mainly at 62°42'N 114°12'W	85J/8	Gates & Hurley, 1973
12	2428±120	bK			AK 124	62°26'N 114°24'W	85J/8	Burwash & Baadsgaard, 1962
13	3210 min.	zU	tonalite	boulders in diatreme at Con Mine ^{207}Pb/^{206}Pb dis. mim.		62°27'N 114°22'W	85J/8	Nikic et al., 1980
13	3300-3040	zU	tonalite	boulders in diatreme at Con Mine ^{207}Pb/^{206}Pb dis. mim.		62°27'N 114°22'W	85J/8	Nikic et al., 1980
13	2900 annealed		tonalite	boulders in diatreme at Con Mine ^{207}Pb/^{206}Pb dis. mim.		62°27'N 114°22'W	85J/8	Nikic et al., 1980
13	2570		quartz monzonite	boulders in diatreme at Con Mine		62°27'N 114°22'W	85J/8	Nikic et al., 1980
14	2510±10	wR	shear zone	4 out 6 pts., (.7003)		Giant YK shear zone	85J/8	R. St.J. Lambert, Geoscience Forum, Yellowknife, Dec., 1982, prelim. data
14	2519±12	wR	felsic volcanics	Banting Fm. 5 pts. in units B.C. (.7021), 1 pt. (A) away from others			85J/8	R. St.J. Lambert, Geoscience Forum, Yellowknife, Dec., 1982, prelim. data
14	2567±10	wR	dacite	Brock townsite flow		62°27'30"N 114°22'W	85J/8	R. St.J. Lambert, Geoscience Forum, Yellowknife, Dec., 1982, prelim. data

TABLE 1 CONTINUED

REF#	AGE	METHOD	ROCK TYPE	COMMENT	SAMPLE NUMBER	LOCATION	NTS	SOURCE
14	2300±130	wR	basalts	n=4 out of 8 (.7017)		Horseshoe Island	85J/8	R. St.J. Lambert, Geoscience Forum, Yellowknife, Dec., 1982, prelim. data
14	1885±80	wR		n=1, point near Akaticho Fault				R. St.J. Lambert, Geoscience Forum, Yellowknife, Dec., 1982, prelim. data
40	2648 Ma 2707 Ma		granite gneiss	Narcisse Lake, possible basement $^{207}\mathrm{Pb}/^{206}\mathrm{Pb}$ dis. mim.		62°45'N 114°29'W	85J/9	Stevens et al., 1983
40	2506±52	hK	granite gneiss	Narcisse Lake, possible basement $^{207}\mathrm{Pb}/^{206}\mathrm{Pb}$ dis. mim.	GSC 81-144	62°45'N 114°29'W	85J/9	Stevens et al., 1983
40	2107±46	bK	granite gneiss	Narcisse Lake, possible basement $^{207}\mathrm{Pb}/^{206}\mathrm{Pb}$ dis. mim.	GSC 81-143	62°45'N 114°29'W	85J/9	Stevens et al., 1983
40	2197±48	bK	granite gneiss	Narcisse Lake, possible basement $^{207}\mathrm{Pb}/^{206}\mathrm{Pb}$ dis. mim.	GSC 81-142	62°45'N 114°29'W	85J/9	Stevens et al., 1983

TABLE 2: TABULATION OF PUBLISHED AGE DATA FROM THE YELLOWKNIFE REGION (N.T.S. 85I, 85J, 85K/W, 85N/SE, 85O/S, 85P/S). ABBREVIATIONS LISTED IN TABLE 3, AGES PLOTTED IN FIGURE 3.

REF#	AGE	METHOD	ROCK TYPE	COMMENT	SAMPLE NUMBER	LOCATION	NTS	SOURCE
15	2555±80	bK	granodiorite gneiss		GSC 63-24	62°43'23"N 113°08'W	85I	Wanless et al., 1965
16	2360±27 2467±28	bK mK	pegmatite	Redout Lake granite	G244	62°44'24"N 113°07'W	85I	Green & Baadsgaard 1971
16	2370±27 2535±27	bK mK	pegmatite	Redout Lake granite	G246	62°44'15"N 113°06'45"W	85I	Green & Baadsgaard 1971
16	2438±27	bK	schist, adj. a shear zone	Redout Lake granite	G253	62°44'32"N 113°04'10"W	85I	Green & Baadsgaard 1971
16	2448±26	mK	pegmatite	Redout Lake granite	G257	62°44'25"N 113°06'42"W	85I	Green & Baadsgaard 1971
16	2535±28	mK	pegmatite	Redout Lake granite	G256	62°44'32"N 113°04'15"W	85I	Green & Baadsgaard 1971
16	2448±26	bK	adamellite	Redout Lake granite	G258	62°45'30"N 113°03'30"W	85I	Green & Baadsgaard 1971
16	2477±28	bK	see G 253	Redout Lake granite	G254	62°44'32"N 113°04'10"W	85I	Green & Baadsgaard 1971
16	2555±16	zU	granitoids	Western Granodiorite, 4 pts. concordia		62°40'N 115°15'W	85J	Green & Baadsgaard 1971
16	2534 min.	zU	adamellite	Western Granodiorite, ^{207}Pb/^{206}Pb dis. mim.	F82	62°48'N 114°23'W	85J	Green & Baadsgaard 1971
16	2451 min.	zU	granitoid	Western Granodiorite, ^{207}Pb/^{206}Pb dis. mim.	FR1	62°50'N 116°02'W	85K	Green & Baadsgaard 1971
16	2184±28 1970±25	mK bK	adamellite	Western Granodiorite, ^{207}Pb/^{206}Pb dis. mim.	G233	62°45'N 115°47'W	85J	Green & Baadsgaard 1971
16	2600 min.	zU	granite	Ross Lake granodiorite ^{207}Pb/^{206}Pb dis. mim.	G259	62°45'45"N 113°03'20"W	85I	Green & Baadsgaard 1971
16	2360±27	bK	granite	Ross Lake granodiorite	G259	62°45'45"N 113°03'20"W	85I	Green & Baadsgaard 1971
16	2457±120	wR	granitoids	n=6, 0.707±0.005	G158	62°47'15"N 113°13'45"W	85I	Green & Baadsgaard 1971
16	2487±28	bK	granitoids	Ross Lake granodiorite	G245	62°44'24"N 113°07'00"W	85I	Green & Baadsgaard 1971
16	2525 min. 2500 min.	zU	adamellite	Ross Lake granodiorite ^{207}Pb/^{206}Pb dis. mim.	GSA GFB	62°37'32"N 115°13'W	85J	Green & Baadsgaard 1971
16	2497±56 2331±27	hK bK	adamellite	Ross Lake granodiorite	G3	62°37'32"N 115°13'W	85J	Green & Baadsgaard 1971
16	2526±56	hK	adamellite	Ross Lake granodiorite	G5	62°38'N 115°13'W	85J	Green & Baadsgaard 1971

TABLE 2 CONTINUED

REF#	AGE	METHOD	ROCK TYPE	COMMENT	SAMPLE NUMBER	LOCATION	NTS	SOURCE
17	2438±100	bK	granitic gneiss	Ross Lake granodiorite	AK 121	62°47'N 113°03'W	85I	Burwash & Baadsgaard 1962
17	2487±100	bK	granite			62°46'N 113°02'W	85I	Burwash & Baadsgaard 1962
18	2482±120	mK	pegmatite		GSC 61-67	62°44'30"N 113°07'W	85I	Lowdon et al., 1963
19	1833±10	wR	volcanic	Seton Fm. n=6 0.7018±		62°01'N 112°03'W	85I	Baadsgaard et al., 1973
20	1795±55	bK	diorite	laccolith	GSC 67-77	62°11'N 112°06'W	85I	Wanless et al., 1969
21	1985±180	wK	diabase		GSC 63-55	62°53'N 114°22'W	85J	Wanless et al., 1965
22	2550±130	mK	quartz monzonite		GSC 61-68	62°45'36"N 113°02'08"W	85I	Lowdon et al., 1963
23	2477±120	bK	granodiorite	Western Granndiorite	GSC 61-64	62°34'N 115°09'W	85J	Lowdon et al., 1963
24	2245±100	bK	granodiorite	Western Granodiorite	AK 1051	62°31'N 114°49'W	85J	Schimann, in Stockwell, 1982.
24	2186±100	bK	granodiorite	Western Granodiorite	AK 1025	62°47'N 116°01'W	85K	Schimann, in Stockwell, 1982
24	2140±100	bK	granite	Western Granodiorite	AK 1045	62°46'N 115°48'W	85J	Schimann, in Stockwell, 1982
24	2011±100	bK	granite	Western Granodiorite	AK 1026	62°50'N 116°03'W	85K	Schimann, in Stockwell, 1982
24	2000±100	bK	granodiorite	Western Granodiorite	AK 1024	62°49'N 115°58'W	85J	Schimann, in Stockwell, 1982
24	1674±80	bK	granodiorite	Western Granodiorite	AK 1028	62°50'N 115°59'W	85J	Schimann, in Stockwell, 1982
24	2294±100 1755±100 1665±80	mK bK bK	granite	Marian Lake granite		62°51'N 116°05'W	85K	Schimann, in Stockwell, 1982
24	2131±100	bK	granite	Marian Lake granite		62°53'N 116°05'W	85K	Schimann, in Stockwell, 1982
24	2163±100	bK	granite	Marian Lake granite		62°52'N 116°04'W	85K	Schimann, in Stockwell, 1982
24	2280±100	bK	diorite	Marian Lake granite		63°02'N 116°15'W	85N	Schimann, in Stockwell, 1982
24	2211±100	bK	granite	Marian Lake granite		62°58'N 116°10'W	85K	Schimann, in Stockwell, 1982
25	2350±120	bK	gneiss	Dogrib Dyke 5 cm from contact	AK 443	62°45'N 113°03'W	85I	Leech, 1966
26	1778±4	wR	diabase	high Rb samples n=2, 0.7130 dyke intrudes granite		62°28'N 114°01'W	85I	Gates & Hurley, 1973
27	2109±47	bK	two-mica granite	Blachford Lake Complex	GSC 78-124	62°06'10"N 112°51'51"W	85I	Wanless et al., 1979

TABLE 2 CONTINUED

REF#	AGE	METHOD	ROCK TYPE	COMMENT	SAMPLE NUMBER	LOCATION	NTS	SOURCE
27	2201±48	mK	two-mica granite	Blachford Lake Complex	GSC 78-125	62°06'10"N 112°51'51"W	85I	Wanless et al., 1979
27	2127±79	hK	quartz syenite Unit 2a	Blachford Lake Complex	GSC 78-126	62°08'11"N 112°45'09"W	85I	Wanless et al., 1979
27	2166±47	bK	granite Unit 4	Blachford Lake Complex	GSC 78-127	62°07'33"N 112°44'27"W	85I	Wanless et al., 1979
27	2133±112	rK	peralkaline granite	Blachford Lake Complex	GSC 78-128	62°07'12"N 112°44'53"W	85I	Wanless et al., 1979
27	3240±59	bK (ear)	hornfels	xenolith in Unit 6	GSC 78-129	62°06'06"N 112°30'24"W	85I	Wanless et al., 1979
27	2150±58	wK	hornfels	xenolith in Unit 6	GSC 78-130	62°07'26"N 112°33'42"W	85I	Wanless et al., 1979
27	2064±46	bK	hornfels	xenolith in Unit 6	GSC 78-131	62°07'26"N 112°33'42"W	85I	Wanless et al., 1979
27	1767±104	wK	diabase	ENE trend	GSC 78-132	62°10'37"N 112°35'35"W	85I	Wanless et al., 1979
27	1791±73	wK	diabase	ENE trend	GSC 78-133	62°08'50"N 112°37'57"W	85I	Wanless et al., 1979
27	1807+74 1808±75	wK	diabase	ENE trend	GSC 78-134	62°07'12"N 112°39'33"W	85I	Wanless et al., 1979
27	1693±67	wK	diabase	ENE trend	GSC 78-135	62°06'13"N 112°51'47"W	85I	Wanless et al., 1979
27	1864±43 (ear?)	bK (ear?)	granodiorite	cut by ENE dykes	GSC 78-136	62°05'50"N 112°39'35"W	85I	Wanless et al., 1979
27	2081±42	wR	quartz syenite	Whiteman Lake syenite		62°08'N 112°45'W (approx.)	85I	Wanless et al., 1979
27	1805±17	wR	volcanics	Seton Fm. details unpublished		62°06'N 112°05'W	85I	Wanless et al., 1979 Cumming, 1980
28	2054±56	rK	granite	Blachford Lake Complex	GSC 76-188	62°08'06"N 112°35'54"W	85I	Wanless et al., 1978
29	2444±52	bK	meta-argillite		GSC 76-183	62°43'N 113°10'W	85I	Wanless et al., 1978
30	2467±64	wK	diabase	Dogrib Dykes (?)	GSC 76-184	62°00'N 113°11'W	85I	Wanless et al., 1978
30	2215±58	wK	diabase		GSC 76-185	62°40'N 112°49'W	85I	Wanless et al., 1978
30	2205±58	wK	diabase		GSC 76-186	62°42'N 112°52'W	85I	Wanless et al., 1978
30	2470±61	wK	diabase		GSC 76-187	62°47'N 112°50'W	85I	Wanless et al., 1978
31	2066±40	wK	gabbro, syenite	Big Spruce Complex		63°33'N 115°57'W	85O	Martineau & Lambert
31	1884±40	wK	pyroxenite	Big Spruce Complex		63°33'N 115°57'W	85O	Martineau & Lambert

TABLE 2 CONTINUED

REF#	AGE	METHOD	ROCK TYPE	COMMENT	SAMPLE NUMBER	LOCATION	NTS	SOURCE
32	1785±90	bK	nepheline syenite	Big Spruce Complex	GSC 62-92	63°33'N 115°57'W	850	Leech et al., 1963
33	2355±120	bK	paragneiss		GSC 61-65	63°17'45"N 114°33'50"W	850	Lowdon et al., 1963
34	2388±120	mK	paraschist		GSC 62-91	63°12'40"N 116°06'20"W	85N	Lowdon, 1961; Leech et al., 1963
34	1900±100	bK	paraschist		GSC 60-46	63°12'40"N 116°06'20"W	85N	Lowdon, 1961; Leech et al., 1963
35	1850±100	bK	quartz monzonite	cuts Snare Group	GSC 60-45	63°28'10"N 116°32'02"W	85N	Lowdon, 1961
36	1945±100	bK	gneiss		GSC 61-72	63°23'15"N 112°20'20"W	85P	Lowdon et al., 1963
37	1804±23	wP	Seton volcanics			62°01'N 112°03'W	85I	Cumming, 1980
38	1811±75	wR	diorite laccolith	unpublished		approx. 62°10'N 112°05'W	85I	Wanless et al., 1979
39	2222±49 2550	bK zU	granodiorite	$^{207}Pb/^{206}Pb$ dis. min.	GSC 81-141	62°46'07"N 112°29'00"W	85I	Stevens et al., 1983

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THE BIG SPRUCE LAKE ALKALINE COMPLEX
PROGRESS REPORT

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SUMMARY

The Big Spruce Lake alkaline silicate-carbonatite complex at 63°33'N, 115°55'W has been remapped and sampled during 1981 and 1982 in preparation for detailed analytical studies. The work planned includes an electron microprobe study of mineral compositional variations, whole-rock analyses, determination of rare earth element and ^{18}O variations in selected samples and a determination of the age of the complex using Nd-Sm isotopes.

INTRODUCTION

The Big Spruce Lake alkaline silicate-carbonatite complex is about 150 km northwest of Yellowknife, NWT (Fig. 1). The main complex, roughly oval in shape and about 3.5 x 9 km, is centered at 63°33'N, 115°55'W. A second small intrusion, the Moose Island complex, has been assumed to be related to the main complex. It consists of a number of small scattered high-potassium mafic bodies exposed within a 10 sq. km area, lying about 5 km southeast of the main complex.

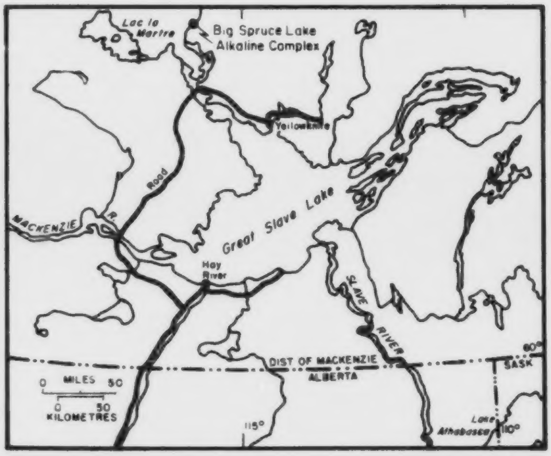

FIGURE 1: Locality plan, Big Spruce Lake Alkaline Complex

The main complex was first mapped by Lord (1942) who noted the diversity of the silicate rock types and the presence of what he believed to be a limestone intruded by the complex. The complex was briefly examined by Lambert (1964), then mapped and described by Martineau (Martineau, 1970; Martineau and Lambert, 1974). Exploration work including trenching and drilling was carried out by Giant Yellowknife Mines Ltd. in 1967-69, but no economically significant rare-element deposits were found.

The objectives of the field work carried out during 1981 and 1982 were to collect samples which are to form the basis of detailed laboratory studies and to verify those features of the original geological map, prepared by M.P. Martineau in 1970, of which knowledge would be essential to future interpretation of laboratory results. The authors feel that both of these objectives have been met, although a possible need for future field work cannot be entirely ruled out at this stage of the study. Any future field work is likely to be of a limited, highly specific nature dictated by future laboratory results.

In 1982, field work was carried out on the Big Spruce Lake complex during a four-week period from mid-June to Mid-July by Patricia A. Cavell (PhD student) and Gordon Bailey (field assistant). Dr. D.G.W. Smith was present for four days of supervision and consultation. Accomodation, supplies and communications were arranged through the facilities of the Northern Canada Power Commission at the Snare Rapids hydro station. The Power Commission also supplied a motor-boat and a canoe, which greatly facilitated travel about the area.

Once again the water level in Big Spruce Lake was extremely low (the lowest since dam construction in 1946), allowing shoreline work begun in 1981 to be extended. Shoreline work in 1982 was concentrated on areas only briefly examined in 1981, and on revisiting areas of special interest. In addition, several traverses inland across contacts and to the outer boundaries were made to complete examination of the complex.

RESULTS OF FIELD WORK

Field work in 1981-82, during which about 1000 rock samples were collected for laboratory studies, resulted in some modifications to Martineau's mapping. Low water levels enabled more accurate placement of some contacts. The outline of the main complex was revised considerably with the discovery of a significant outcrop of foyaite to the southeast of the main complex as outlined by Martineau. Several previously unmapped exposures of dolomite carbonatite (in the main complex) and shonkinite/biotite pyroxinite (in the Moose Island Complex) were noted. Some dikes mapped by Marineau proved to be rafts or more complex bodies, and several previously unnoticed structures such as shear zones were mapped.

GEOLOGY AND PETROGRAPHY OF THE COMPLEX

The complex is about 60% covered by the water of Big Spruce Lake, which is the reservoir for the Northern Canada Power Commission Snare Rapids hydro plant, but the now well-exposed shorelines of the mainland and numerous islands afford excellent sections through the complex and largely offset the disadvantages of the water-covered area.

The topography is (approximately) a peneplaned surface about 20 m above lake level, criss-crossed by numerous gullies that are often floored by muskeg. The major south-trending Snare fault cuts the complex, entering the area along the Snare River channel in the north and exiting at the southeastern corner of the lake. The complex intrudes granitic to granodioritic gneisses lying at the western edge of the Slave Structural Province.

Alkaline silicate activity within the complex can be readily divided into four centres, each of which is petrographicallly and geographically distinct from the other three. Field relations indicate a simple time sequence as well (Fig. 2). Activity within the main complex appears to have begun in the northeast corner of the complex, emplacing diorite and gabbros (Centre 1), then to have moved southwest to emplace syenites (Centre 2) followed by nepheline-rich rocks still further to the southwest (Centre 3). The relationship of the silicates of the isolated Moose Island centre to those of the main complex has not yet been determined. Following Martineau's (1970) terminology, they are listed as Centre 4, the final silicate activity.

Carbonatites are temporally and petrographically, but not entirely geographically, separate from the silicates of the main complex. Dolomitic rocks intrude gneisses immediately east of the complex, but calcitic intrusives lie mainly within the western boundary of the complex cutting Centres 2 and 3. Carbonatites have been grouped as Centre 5 of the complex.

The first centre of igneous activity (Centre 1), to the northeast of the lake, is an intermediate to basic, layered ring complex about 1.5 km in diameter. The centre is cut by several faults. Numerous ridges provide good sampling localities but exposure over much of the inland area is poor, obscured by muskeg, lichen and undergrowth.

The geological map of the complex prepared by Martineau (1970) was the result of field work during 1967-1968, following a major forest fire down the east side of Big Spruce Lake in 1964. The much-improved exposure produced by the fire allowed a fuller examination of features such as banding and igneous laminations as well as contacts, hence much of the detail of the present (preliminary) geological map of Centre 1 is based on the original work. In particular, much of the northwest zone of Centre 1 is very poorly exposed, but the presence and positions of the syenite ring dyke and the diorite in that area (as originally mapped by Martineau) have been confirmed, as has the presence, but not the complete extent, of the pyroxenite.

The first unit of Centre 1 is an outer-ring diorite (up to 800 m wide as presently exposed) showing a mafic chill against granodioritic gneiss to the northeast and grading to a leucocratic, somewhat laminated type towards the centre. This is followed by the central gabbro units. A generally massive feldspar gabbro unit is chilled against diorite and grades transitionally into a more leucocratic, well laminated unit (leucocratic laminated gabbro) that in turns grades rapidly into a striking rhythmically banded unit which forms the centre of the intrusion (rhythmic banded gabbro).

Solidification of the gabbros was followed by intrusion of magnetite pyroxenite, mainly on the western edge of the centre, although many small pyroxenite units cut the more central gabbros. Pyroxenite activity may have extended to several magma pulses over a period of time. The large pyroxenite unit to the northwest is cut by a large fault through Arete Lake with sinistral movement, yet pyroxenite fills the fault zone and forms the arete for which the lake is named. Pyroxenite also intrudes the syenites of Centre 2 at their northern edge.

Initial petrographic study suggests that the final stage of diorite and gabbro crystallisation was pervasive low-grade autometasomatism or late deuteric chloritization and saussuritization. The diorites and gabbros show a greater degree of alteration than do the pyroxenites in which the augitic pyroxene is relatively fresh.

Although pyroxenite activity may have continued in the northeast area following movement on the fault through Arete Lake, the main magmatic activity of the complex began to move to the southwest and changed abruptly from intermediate/basic to syenitic.

The syenites of the second centre of activity form a somewhat discontinuous ring dyke (exposed width 100 m) around Centre 1, and a main arcuate body (3 km diameter) which is centered in the lake northeast of Big Spruce Island, and exposed on both sides of the lake as well as on several islands. A small syenitic body, which is distinct geographically (Island G) and petrographically, is exposed between the main centres of intermediate/basic and syenitic activity.

Division of the syenites, apart from the mafic syenite, into separate units is not obvious. The ring dyke around Centre 1 may be a separate unit, although in the field no contact of significant difference between it and the other syenite(s) adjacent to it at the south end of Centre 1 could be distinguished. Mineralogical or compositional differences may be clear following detailed analytical work.

In the field, the main arcuate syenite body is not readily separated into individual units because visible criteria such as colour, texture and mineralogy appear to vary as much within possibly separate units as between units. On the west side of the lake an internal contact was established at the position of the large basic dyke shown by Martineau as lying between syenite units. At this contact an early coarse-grained outer syenite, lying to the west, was intruded by a more mafic (at least in the chill) syenitic magma. This later syenite forms a clean contact against coarse syenite on the west and encloses large blocks of coarse syenite, in a zone up to about 25 m from the contact, on the eastern side. This internal contact can be traced to points north and south of the original exposure on the west side of the lake, but no such syenite/syenite contact could be found either in the area where it would approach the lakeshore at the northern edge of the complex, or on the east side of the lake.

The syenites examined to date all consist largely or perthitic alkali feldspar with interstitial aggregates of brown amphibole, near ferrohastingite in composition, pale-green pyroxene, olive green biotite, variable amounts of quartz and iron-titanium oxides along with accessory apatite, zircon, and allanite. Late, low-temperature alteration is evident not only in the perthitic feldspars but also in the alteration of amphiboles, exsolution and replacement textures of iron-titanium oxides and in the presence of stilpnomelane in many of the samples.

Stilpnomelane, which is generally regarded as a

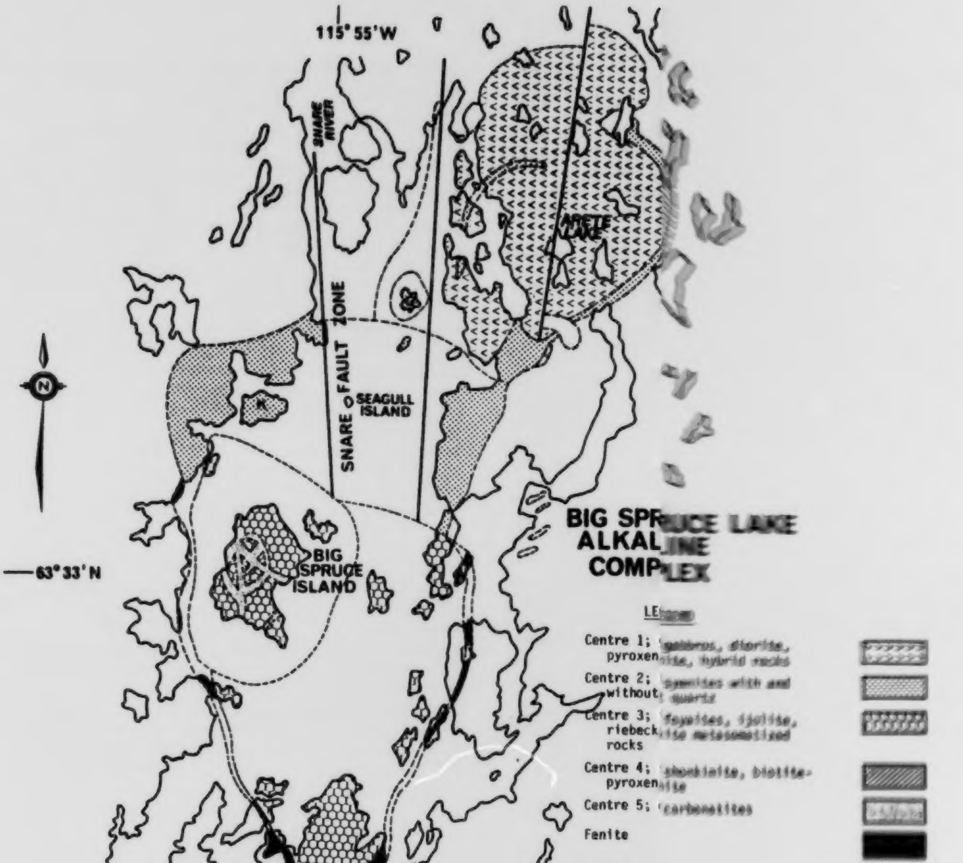
115° 55'W
63° 33'N
N
SNARE RIVER
SNARE FAULT ZONE
SEAGULL ISLAND
ARETE LAKE
BIG SPRUCE ISLAND
BIG SPRUCE LAKE ALKALINE COMPLEX
LEGEND
Centre 1; gabbros, diorite, pyroxenite, hybrid rocks
Centre 2; syenites with and without quartz
Centre 3; foyaites, ijolite, riebeckite metasomatized rocks
Centre 4; shonkinite, biotite-pyroxenite
Centre 5; carbonatites
Fenite
Fault
MOOSE ISLAND COMPLEX

FIGURE 2: Geological centres, Big Spruce Lake and Moose Island complexes.

metamorphic mineral of the greenschist facies, appears mainly in the outer syenites and is usually accompanied by carbonate and fine-grained quartz. The occurrence of this mineral appears to indicate a very localized, fluid-rich alteration which may be late deuteric or it may be related to the very late carbonatite activity of Centre 3. That regional metamorphism to greenschist facies has not occurred is shown by the presence of unaltered biotite, amphiboles and pyroxenes throughout the main complex as well as at Moose Island. If the presence of stilpnomelane can be linked to a single syenite unit (by petrographic and possibly isotopic examination of surrounding gneisses as well as other syenites) this would strongly suggest that late deuteric action is responsible.

The southern edge of the red-brown weathering syenites is sharply cut by chilled, grey, nepheline-rich rocks and the contact is well exposed on both sides of the lake. This third centre of silicate activity, lying still further to the southwest, clearly emplaced magmas whose compositions lie on the undersaturated side of the thermal divide (Ab-Or tie line) in the Ne-Ks-Q triangle or leucocratic residua system. The relationship between saturated and undersaturated magmas may be clarified by examination of the porphyry dykes of the complex. Centres 1 and 2 as well as the surrounding gneisses are crosscut by a variety of porphyry dykes bearing nepheline and/or alkali feldspar phenocrysts in varying sizes and proportions. The matrix is usually mafic rich and may contain carbonate. These dykes apparently never cut the undersaturated rocks of Centre 3, hence temporally the porphyry dykes lie between saturated and undersaturated activity. As a group they may also bridge the compositional gap. Several crosscutting relationships betwen porphyries were recorded and samples taken from the now well-exposed gneissic shoreline at the north end of the lake. It is hoped that these samples will show an evolutionary trend in their major and trace element (rare earths, Zr, Th, U, etc.) patterns which can be related to the magmas of Centres 2 and 3.

Centre 3 consists of grey to black nepheline-rich rocks, extremely variable in textures and modal compositions. Much of this centre is under water; the remaining rocks rim the southern half of the lake in an oval roughly 2.5 by 4.0 km. They also form Big Spruce Island, Little Spruce Island and the small islands of the southeast. The major portion of the area is underlain by leucocratic light-grey rocks composed of nepheline and alkali feldspar in widely varying proportions and accompanied by aegirine-augite, iron-titanium oxides, sphene, sodalite, fluorite, and apatite. The textures range from a laminated chill to a very coarse or pegmatitic feldspathic phase. These are the southern foyaites. Big Spruce Island is composed of a similar but more mesocratic dark-grey foyaite (northern foyaite) that has been intruded by even more mafic black ijolite. Much of the rock on Little Spruce Island, lying just to the north of Big Spruce Island, has been very highly altered by subsequent carbonatite activity, but the host rock appears to be the same mafic foyaite as appears on Big Spruce Island. Contacts between the northern and southern foyaites lie beneath the water, but a small zone of ijolitic breccia on the south-eastern tip of Big Spruce Island carries clasts of leucocratic foyaite from which it is inferred that the mafic types post-date the leucocratic southern foyaite.

The contacts between syenites and foyaites presently exposed at two locales on the east and west shores of the lake show very different characters. On the western side, mafic foyaite, sharply chilled against syenite, carries a few small, sub-rounded, clasts (up to 20 cm across), of fine-grained foyaite and coarse syenite near the contact. However, within 2 m, well-defined layers of mafic minerals have developed. Two episodes of crystallization are thus represented at this one locale, the second, which produced the layering, apparently continued relatively undisturbed. On the east side a more complex contact zone between syenite and the leucocratic southern foyaite is now clearly exposed. The contact itself is not sharp. Highly altered syenite is transitional to fine-grained grey foyaite over an interval of about 1 m. Much of the foyaite adjacent to the syenite carries euhedral nepheline phenocrysts (to 1 cm in size) but there is no foliation or alignment. Beginning within this transitional contact interval and extending up to 5-7 m within the foyaite body is a border zone. The fine- to medium-grained "host" foyaite shows no layering, but the modal mineralogy commonly varies over short intervals (0.5 m) from nepheline-rich, to feldspar-rich and a few small lenses (10-25 cm in size) of pegmatitic feldspar rock have developed. This variable foyaite carries many clasts ranging in size up to 1.5 m. These rounded to subrounded clasts are largely foyaitic and some are themselves either extremely variable in modal mineralogy (e.g. with zones of ijolite or of sodalite-foyaite) or composites of still earlier phases. This border zone thus represents several episodes of crystallization, fracturing and intrusion. The 'host' foyaite(s) (which cannot be followed as a continuous phase) tends to coarsen away from the syenite and the border zone passes into coarse leucocratic foyaite. No true layering could be observed above the border zone but about 50 m inside the contact, oriented lenses (2-3 m in size) of feldspar pegmatite, urtite and ijolite occur.

The southern foyaite/gneiss contacts also show two different characters. Across the southern edge of the foyaite is a very transitional contact. In general, the rocks pass first from coarse, grey feldspathic foyaite to coarse, red feldspathic syenite differing mainly in colour. Continuing away from the foyaite the texture becomes granular gneissic, the colour fades to pink and quartz begins to appear. The width of the fenite zone varies widely as is indicated on the geological map. Each of the transitions mentioned can be patchy and discontinuous, with red syenitic lenses appearing in grey foyaite, or quartz-bearing gneissic lenses appearing within a red feldspathic zone. In contrast to the transitional contact to the south, on the eastern and western edges, parallel to the direction of shearing connected with the Snare fault, the gneiss at the contact with foyaite is remobilised. It shows the development of fluidised textures and possibly the injection of new mafic material into the granitic gneisses.

The main body of the foyaite is inhomogeneous in both texture and modal mineralogy, but no pattern of variation could be discerned. Textures vary from medium grained to very coarse, sometimes within a single small outcrop. Nepheline is usually minor or absent in the coarsest phases. The entire body is crosscut by leucocratic feldspar porphyry dykes and by tinguaite dykes and veins. Thus both the contact zone and the main body of southern foyaite show a pattern of crystallization followed by fracturing and continued undersaturated magmatic activity.

Initial petrographic study of the foyaites and ijolites shows strong evidence of disequilibrium in the form of resorption and recrystallization. Early nepheline and alkali feldspar phenocrysts exhibit compositional zoning, rings of inclusions and resorbed edges. They are often replaced partly or completely by granular aggregates of secondary minerals such as cancrinite, albite, nepheline and fluorite. The main mafic mineral is aegirine-augite that has a significant manganese content. It too is often resorbed and may be rimmed with granular andradite garnet. The presence of this garnet in ijolite samples from on and near Big Spruce Island may be related to high-grade fenitization processes caused by carbonate activity (Baer, et al., 1978, p. 589).

In the area 5 km southeast of the main complex, the high-potassium mafic rocks that represent the fourth centre of silicate activity are exposed as scattered bodies of shonkinite, biotite pyroxenite and a few minette dykes. The shape and character of the main intrusive body, if one exists, is difficult to determine with any degree of certainty because the area is largely covered by water.

On the basis of available evidence, Martineau (1970) suggested an arcuate dyke form surrounded by a number of small pipes. The low water levels of 1981 and 1982 revealed several exposures of intrusives and gneiss that cast doubt on this theory.

The typical dyke form, near vertical and strongly linear (or arcuate in this case), is missing. The largest exposed portion of the 'dyke' crosses a large island at the centre of the area, where individual outcrops suggest that shonkinite underlies gneiss in a sill-like form. In addition, the continuous dyke form outlined by Martineau is clearly interrupted by gneiss that is now exposed just to the southeast of the previously described sill-like exposures. Several previously unmapped outcrops of mafic intrusions have been newly or better exposed by the low water levels. Three of these ring the northwestern end of the original 'dyke' and their positions, in conjunction with the previously mapped intrusions, greatly increase the probability of the existence of a single body now covered by water. Another newly mapped mafic body lies along the shoreline, between previously mapped units, at the southeast end of the 'dyke', increasing the suggested size of the body present at that location.

An additional small shonkinitic pipe carrying many gneissic blocks was mapped on the northern edge of the area.

All of the small pipes surrounding the central area carry sub-angular to rounded gneissic inclusions up to 1 m in size. These suggest much wall-rock interaction at the boundaries, perhaps indicating that the rocks presently exposed represent the upper levels reached by the intrusion.

Field evidence now suggests that if a single intrusive body exists, the main portion lies at depth with major upward extensions centered in the water-covered areas to the northwest and southeast ends of the dyke form originally suggested by Martineau. The many small pipe-like bodies that lie around the main centre of intrusion and are unconnected on the surface may be individual upward fingers from a single parent body.

Following the alkaline silicate activity of the main complex various carbonates were emplaced. The carbonate rocks can be divided into two groups, (1) various calcitic rocks, largely within the main complex on the western side of the lake, and (2) dolomitic rocks in the gneisses just outside the east side of the main complex.

A preliminary stable isotope (^{13}C and ^{18}O) study of some of the calcitic rocks reported by Smith and Cavell (1983), clearly showed them to be of magmatic origin and hence carbonatites. The calcitic carbonatites are extremely varied in intrusive form and in composition. They occur as:

(i) Well-formed dykes up to 3 m in width. The calcite carbonatite dykes fall into three groups based on mineralogy. Cutting gneiss to the west of Big Spruce Island is a medium to coarse-grained, manganese-rich, pink calcite that bears phenocrysts of pyrite (to 1 cm) and magnetite (to 1 mm) as well as fine-grained quartz. Massive quartz is closely associated with this dyke as well. To the northeast of Big Spruce Island the dyke(s) cut foyaite and syenite and are fine to medium grained and bear riebeckite and fluorite, which sometimes impart a violet-blue colour. On Little Spruce Island the carbonatite dykes are commonly grey and foliated, the colour being derived from mafic agglomerates of a rare-earth silicate accompanied by riebeckite and sphene, and the foliation appears to be due to flow, sometimes around feldspathic country rock inclusions. A similar grey carbonatite occurs on one of the small islets immediately west of Big Spruce Island.

(ii) Coarse-grained rocks with silicate in all proportions. Units of these rocks commonly exhibit no clear field relations. Many of these are found on an islet immediately west of Big Spruce Island and on Little Spruce Island. These rocks may be primary in origin or hybrids due to interaction of host foyaite or ijolite with a later carbonate phase.

(iii) A carbonated minette breccia pipe in the gneiss immediately west of Big Spruce Island. The pipe, 10-15 m in diameter, carries subrounded fragments up to 1.25 m across, of gneiss, mafic intrusives (ijolite?) foyaite and porphyry dyke rock.

(iv) A radial and concentric pattern of recessive rocks outlined in the foliage pattern on Big Spruce Island that Martineau (1970) describes as due to shear zones floored by calcite carbonatite pegmatite. Some of the pattern that is shown on Martineau's map can be clearly seen on the original air photographs, taken in 1946, but other portions are not so well defined. Much of the pattern discernible on the 1946 photographs has been either altered or obliterated by exploration work (trenching) carried out by Giant Yellowknife Mines Ltd. in 1967-1969. The distinctive pattern shown in the oblique aerial photographs taken during field work in 1982 is largely man-made.

In general, exposure on Big Spruce Island is very poor, with muskeg-covered inlands and a sandy/rubbly shoreline. During 1981 and 1982, several traverses were made and bedrock on and near the "roads" uncovered by Giant Yellowknife Mines was examined and sampled, but no pegmatitic carbonatite was found on Big Spruce Island. Rubble on the western shore, where the concentric pattern intersects the waterline, showed much coarse-grained magnetite and weathered coarse-grained biotite that might be related to the pegmatitic carbonatite reported to underlie the radial and concentric pattern. A second outcrop, which also may be related to the recessive pattern on Big Spruce Island, was recorded at the southwest shoreline directly on the line of one radial arm of the pattern visible in the foliage. A dome of coarse foyaite, about 3 m in diameter and about 2 m high, is criss-crossed by veins up to 10 cm wide that are infilled with very coarse biotite and magnetite. One veinlet of carbonate and fluorite cuts this dome, which is surrounded by moss-covered rubble."

The large limestone lens with abundant fluorite (carbonatite?) reported by Lord (1942) to lie in syenite at the southeast tip of Island K was not found in spite of the 4 m drop in water level.

Although calcitic activity was centered on and around Big Spruce Island, the entire complex and surrounding area are cut by veins and small dykes assumed to be part of the final carbonate phase. Typically these dykes are coarsely foliated or composite with mafics (commonly biotite) plus quartz and carbonate and often fluorite.

All significant dolomite exposures lie just outside the complex. These carbonatites are dykes and pipes cutting gneissic country rock. The largest is a pipe about 10-12 m in diameter which extends to a height of 20 m through and above the surrounding gneiss. It carries many xenoliths of fenitized gneiss, and may itself be slightly brecciated. Around this pipe lie several slightly arcuate and concentric dolomite dykes, one of which trends easterly to connect with a second smaller pipe. In this second pipe, phenocrysts of magnetite up to 0.5 cm across are weathered out at the surface. Two additional small pipes were found on Island P during 1982. These are the westernmost dolomites yet mapped. Other small exposures of dolomite may well exist, on the linear trend predicted by Martineau, in the covered area to the northeast of the largest pipe or dome. The mineralogy and compositions of the dolomites have not yet been examined.

RELATIONSHIP OF THE COMPLEX TO THE SURROUNDING AREA

According to Sorenson (1974), while some alkaline rocks occur in mobile belts, most are formed in tectonically quiet regions with the specific locations of intrusions controlled by deep faulting. It is to this latter group that the Big Spruce Lake complex belongs.

This intrusion lies in a lobe of granitic to granodioritic gneiss within the Slave Structural Province, just 30 km from the boundary with the Bear province to the west. The gneisses are Archean and the area has remained essentially stable over the past 2.4 b.y. (McGlynn and Henderson, 1972).

AGE

The age of the Big Spruce Lake intrusion is not yet known with certainty. K-Ar data obtained from biotites from the complex gave dates of 1785 m.y. (Leech, et al., 1963) and 1820 m.y. (Lambert, pers. comm., 1980). Rb-Sr data (Lambert, pers. comm., 1980) did not produce an isochron, but suggest dates of about 2170 m.y. for the main complex and 980 m.y. for the subsidiary potassium-rich Moose Island complex. Data for the gneissic country rock gave a minimum age of 2400±50 m.y. (Lambert, pers. comm., 1980).

The Rb-Sr data for the complex itself are very scattered due, in part, to very high Sr and low Rb contents that lead to a low proportion of radiogenic Sr. The scatter may also arise from a slightly variable initial $^{87}Sr/^{86}Sr$ ratio (Rock, 1976) or from the fact that Rb and Sr can exhibit differential mobility during low grade metamorphism or metasomatism (Faure, 1977) such as has been noted in the silicates of the main complex at Big Spruce Lake. Additional evidence of a low grade metamorphic event in the Big Spruce Lake area is a discordance of K-Ar ages obtained so far. K-Ar ages have not been determined on the gneisses immediately surrounding the complex, but biotite specimens from gneisses from the north and south edges of the lake in which the complex lies, taken nearer the Bear-Slave boundary, both show discordant muscovite and biotite ages (Leech, et al., 1963). Biotites were reset at 1880 and 1785 m.y. (the K-Ar age of biotite from Big Spruce Lake) while the corresponding muscovites gave identical ages of 2400 m.y. Biotite is reset at a lower "threshold" than is muscovite (Faure, 1977).

Examination of presently available evidence suggests that the complex has a true age of emplacement of about 2100-2200 m.y. into a lobe of 2400 m.y. (or older) gneiss, and that a mild metamorphic event at about 1800 m.y. has left an overprint on the biotite. The Big Spruce Lake intrusion is thus one of the oldest recorded carbonatite-alkaline rock complexes in the world.

If the Big Spruce Lake complex is 2100-2200 m.a. then it can be correlated in age with the two alkaline bodies reported in the East Arm of Great Slave Lake, the Blachford Lake alkali granite complex (about 2057 m.y., Davidson, 1978) and the Simpson Islands dyke (2170 m.y., Leech et al.,1963; 2200 m.y., Burwash et al., 1962).

STRUCTURAL CONTROL OF LOCATION

Both the intrusion and the enclosing gneiss are cut by the major North-South Snare Fault, whose strong expression on aerial and Landsat photographs suggests that it is deep and near vertical. The fault was mapped, in part, by Lord (1942) who considered it to be vertical with sinistral movement. An offset of about 0.7-1.0 km has occured in metasediments of the Yellowknife Supergroup at a point just south of Kwejinne Lake, about 12 km north of Big Spruce Lake. The age of the Yellowknife metasediments has been placed at about 2400-2480 m.y. (Lowdon, 1961; Leech, 1963) and movement on the fault clearly is later, but more specific information is not yet available, partly because the age of the Big Spruce Lake complex is unknown.

Movement along the Snare Fault probably began before intrusion of the complex since deep fracturing of some type is necessary to form a conduit for magma. It is assumed that action on this fault controlled the actual location of the intrusion.

The Snare Fault was active during at least part of the intrusive activity. Several items of field evidence in support of this statement have been cited by Martineau (1970). The most significant observation is that the gabbros and pyroxenite of the northeast corner are offset by a northeast-trending fault assumed to be a splay of the Snare system. Activity along this fracture apparently ended prior to emplacement of the later syenites because the syenite composing the ring dyke around the southern portion of Centre 1 is continuous across the fault line, and shows no offset or shearing.

Little significant post-intrusive lateral movement can be positively identified from the field evidence, but activity probably continued on the main fault at least long enough to shear the units of the complex that span the fault zone. Lord (1942) in his observations of exposures now covered by a higher water level, noted crushed syenitic and granitic rocks on a small island near the north end of the lake and hence he placed the fault through what is now labelled Seagull Island. The presence and shape of the lake itself at the centre of the complex suggests a post-intrusive weakness in the rocks below.

Martineau (1970) suggests that the complex lies at the intersection of the Snare Fault with a second major fault trending roughly northeast to southwest. While this may indeed be so and a computer assisted analysis of the aeromagnetic data for the Big Spruce Lake area suggests that an east-west structure of some kind played a part in the emplacement of the complex, there is at present no direct evidence for a second major fault of similar magnitude to the Snare. Examination of Landsat photographs that have become available since Martineau's work do show a very strong lineament trending northeast from Big Spruce Lake through Ghost Lake (40-50 km away). It continues along the Snare River channel where it was mapped by Lord as a fault at a distance of 80-100 km from Big Spruce Lake. However, no part of this fault has yet been mapped nearer than 80 km from Big Spruce Lake (G.S.C. Open File Map #445, 1977) and perhaps more significantly, no expression of it around Big Spruce Lake is visible in the Landsat photographs. No northeast trending fault, comparable in size to the Snare Fault, passes through the complex.

The fault actually outlined by Martineau (1970) is a smaller, more localised one that does indeed intersect the Snare Fault at Big Spruce Lake and may have helped to control the location of the intrusion (Fig. 3).

FIGURE 3: Composite Landsat photograph with Big Spruce Lake shown in black. The field of view spans about 150 km. A lineament analysis map centerd on Big Spruce Lake is shown in Figure 4.

Field observations suggest a third possibility for structural control over emplacement location. The major or deep Snare Fault appears to shift its position slightly as it passes through Big Spruce Lake, exiting at the south end somewhat to the east of the line on which it enters from the north. While this shift could be due to offset by a cross-cutting fault, it is unnecessary to have a second fault present. Faults of all sizes can, due to inhomogeneities in the crust, divide into a series of smaller parallel fractures connected by local cross-cutting fractures. Such a development would form a zone of block-faulted crust. Had this occurred on the major Snare Fault, it alone could form a conduit or zone of weakness for emplacement at Big Spruce Lake.

The exact nature of structural control over the location of the Big Spruce Lake intrusive complex cannot be deduced from the present evidence and more detailed speculation is unwarranted at this time.

CONCLUSION

(1) Field work is now essentially complete with many new exposures being sampled due to a drop in water level.

(2) Some modifications and additions to Martineau's (1970) map have been made as a result of the two seasons of field work and improved exposures.

(3) A program of laboratory work has been planned, of an essentially mineralogical, chemical and isotopic nature, to try to answer some or all of the following questions:

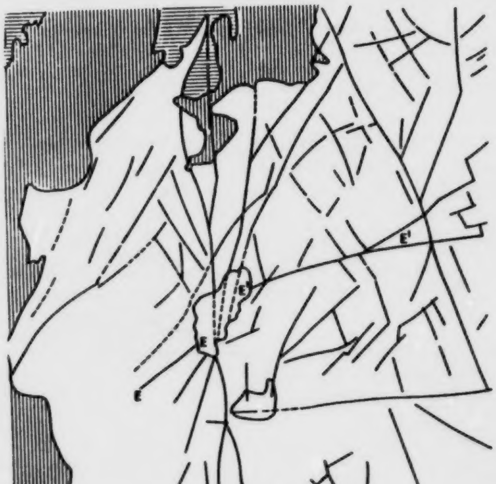

FIGURE 4: Lineament analysis map, Big Spruce Lake region. The intersecting fault system as outlined by Martineau comprises the Snare Fault System (N-S trends) and the offset E-W trend marked E-E and E'-E'. Note that this latter trend is much weaker than the Snare Fault System in Figure 3.

(i) What is the petrogenetic sequence within each centre of igneous activity?

(ii) What are the petrogenetic relationships between the rocks of different centers?

(iii) What is the relationship of the Moose Island complex to the main complex?

(iv) What mineralogical variations are associated with the sequence of events within and between centres?

(v) What is the nature and extent of the fenitisation processes that are evident around the nepheline-rich centre?

(vi) What is the age of the complex and its components?

(vii) What is the relationship of the intrusion to structural features, the depth and temperatue of magma generation, the temperature and pressure of crystallisation? How deep was the present erosion level at the time of crystallisation?

(viii) What were the ages and causes of any metamorphic events which post-date the Big Spruce Lake intrusion?

(ix) Is there any relationship between this intrusion and the alkali granite at Blachford Lake, or the Simpson Islands dyke?

(4) No economic deposits of rare elements have been found.

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SEDIMENTOLOGY AND STRATIGRAPHY OF A MIDDLE-UPPER DEVONIAN SEQUENCE IN THE POWELL CREEK AREA, NWT.

Preliminary Project Report by

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University of Ottawa

INTRODUCTION

Middle and Upper Devonian sequences were examined in the Powell Creek - Bell Creek area at the Mackenzie Mountain front (65°16'N; 128°46'W - 129°04'W) approximately 110 km west of Norman Wells, NWT (Fig. 1).

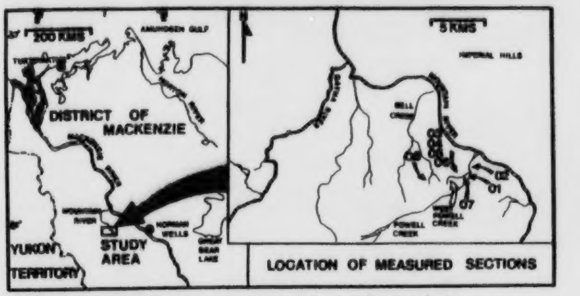

FIGURE 1: Index map showing measured sections

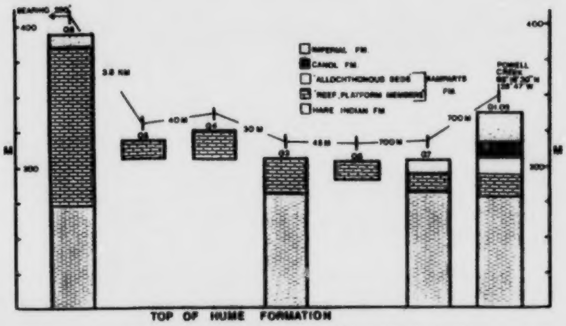

FIGURE 2: Measured sections in the study area

The main purpose of the first field season (1982) was to recognize and document lithofacies and biofacies associations in the Ramparts Formation (Kee Scarp Formation of Bassett, 1961, and others). The Ramparts Formation is a Givetian platform reef complex (Tassonyi, 1969) and is the reservoir for the Norman Wells oil field.

Detailed study of closely spaced sections and lateral tracing of units permitted documentation of facies changes that might otherwise be difficult to ascertain in subsurface studies. Microfacies and biofacies research are currently being conducted by the author at the University of Ottawa.

STRATIGRAPHY AND SEDIMENTOLOGY

Devonian stratigraphy in the Mackenzie Mountains - Norman Wells area (Fig. 3) has been discussed by numerous authors (including Aitken, Cook and Yorath, 1982; Bassett, 1961; Braun, 1978; Tassonyi, 1969). This report augments certain aspects of their work as it pertains to the study area.

HUME FORMATION

The Hume Formation is a fossiliferous limestone sequence with shale interbeds that are more subordinate towards the top of the formation (Tassonyi, 1969). In the Powell Creek area, the Hume Formation is approximately 138 m thick (Uyeno, 1978) and is entirely of Eifelian age (Braun, 1978). However, according to Lenz and Pedder (1972), the uppermost beds (approx. 2 m thick) are Givetian. The top of the Hume Formation has been selected as the basal datum for measured sections in the study area (Fig. 2).

(A) LITHOFACIES: only the uppermost 5 m of the Hume Formation were examined and the following lithofacies were observed:

(i) Nodular wackestones - mudstones are thinly bedded, medium brown-grey and become darker towards the top of the formation where they are abruptly

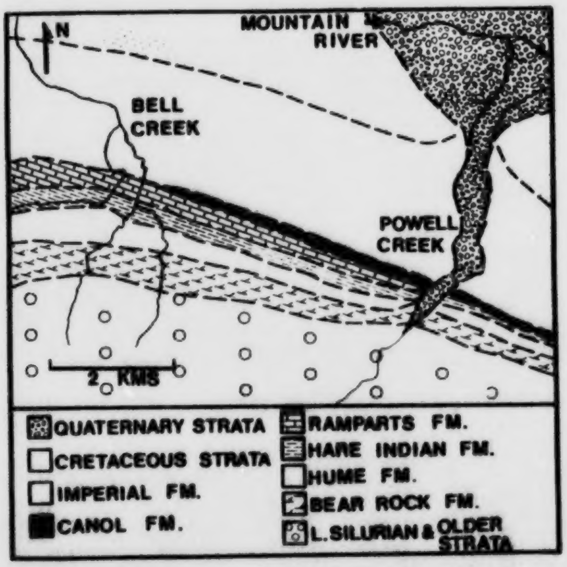

FIGURE 3: Geology and Middle Devonian stratigraphy in the study area (after Aitken and others, 1982)

overlain by black bituminous shale of the Hare Indian Formation. Open marine faunal elements tend to be concentrated near the upper bedding contacts and commonly show iron mineral stains (probably after pyrite). Rhynchonellid (esp. *Leiorhynchus castanea*) and atrypid brachiopods as well as abundant pelagic fauna (styliolinids and tentaculitids) are predominant. Minor faunal elements include fenestellid bryozoans, gastropods and bivalves, with tabular favositid and solitary rugose corals in the lowermost beds. The rocks show thorough bioturbation. Geopetal fills in some brachiopod valves suggest primary depositional slopes of 5-15°. Stylolites are less prevalent towards the top of the formation and there is a corresponding change from planar to nodular bedding, decrease in bedding thickness, and increase in disseminated pyrite.

(ii) Green-gray calcareous shale is gradually interbedded with the nodular wackestone-mudstone lithofacies and abruptly encloses the latter units where nodular bedding is well developed. Wavy to wispy laminae and endichnial trace fossils indicate extensive bioturbation. The shale is medium-dark in color and shows papery fissility. Faunal elements include lingulid brachiopods, and common styliolinids and tentaculitids. Other biota include bivalves and *Leiorhynchus* coquinas.

(B) PALEOENVIRONMENTAL SYNTHESIS: Tassonyi (1969), Gilbert (1973), and others, have suggested that the Hume Formation represents deposition in a gradually deepening shelf environment. The shale-dominated Hare Indian Formation abruptly overlies the Hume Formation with no apparent evidence of erosion. However, the prevalent nodular bedding style, pyritization of bed tops and condensed faunal elements in the uppermost 2 m of the Hume Formation may indicate submarine hardground development prior to Hare Indian shale deposition. The top of the limestone sequence may prove to be a useful synchronous time marker in the Norman Wells area, although a gradational interbedded upper contact has been reported in other localities (Tassonyi, 1969 - Circle River area).

HARE INDIAN FORMATION

The Hare Indian Formation consists of a lower black bituminous shale member (average 12 m thick) with rare carbonate concretions and "fibrous calcite" beds (MacKenzie, 1972), and an overlying lighter coloured green shale-argillaceous limestone member. The upper contact of the Hare Indian Formation is gradational with the Ramparts Formation and probably diachronous (Aitken et al., 1982). The top of the Hare Indian Formation was arbitrarily placed where limestones become pre-dominant. The Hare Indian Formation thins from 165 m at W. Powell Creek to 147 m at Bell Creek (8 km west).

(A) LITHOFACIES:

(i) Bituminous black shale is restricted to the basal Hare Indian Formation. The dark brown-grey lithofacies tends to be recessive and only the basal 2-12 m were exposed in the study area. Parallel horizontal stratification predominates and bioturbation appears to have been minimal. Papery fissility may be related to abundant thin coquinas (tentaculitids and styliolinids) as well as to variable carbonate content. Dark grey, pyritized terrigenous clastic carbonate mudstone concretions (long axis = 0.3-0.5 m) occur rarely, but only in the basal 2 m of the Hare Indian Formation. A low-diversity pelagic fauna predominates, although rarely lingulid brachiopods, plant fragments, high spired gastropods and three varieties of bivalves are present.

(ii) Calcareous mudstone-shale lithofacies (medium green-grey to brown-grey) become darker and subordinate to calcisiltite lithofacies towards the top of the Hare Indian Formation, i.e. a decreasing mud/sand ratio or coarsening-upwards (CU) trend. The shales show gradational bed contacts with the calcisiltite lithofacies in the lower portion of the upper member but are planar-abrupt to compacted around calcisiltite nodular beds in the upper portion (Fig. 4). The shales rarely show dark and light-coloured interlaminations possibly reflecting variable carbonate content. Wispy, bioturbated and horizontal parallel laminae are the dominant strata types. Some of the latter show normal grading. Upper bed contacts tend to be planar-abrupt and basal contacts range from gradational and bioturbated to planar-abrupt. Minor ptygmatic slump folds are present and rare iron-rich carbonate concretions are restricted to beds near the top of the Hare Indian Formation. Pyrite is a common accessory mineral. Fossils that occur rarely include: styliolinids, crinoidal debris, plant fragments, lingulid brachiopods, small bivalves and ganoid fish fragments.

(iii) Calcisiltite lithofacies displays an over-all upward transition from planar to nodular bedding style within the Hare Indian Formation. Slump structures, syndepositional faulting, clastic dykes and abundant load casts are present in the calcisiltite lithofacies. Although some calcisiltites display rare low-angle stratification and ripple cross-stratification, indistinct horizontal-parallel to wavy laminae are the major preserved stratification types (Fig. 5). Fossils tend to be more diverse and abundant than in the mudstone-shale lithofacies, and include: plant debris, fish fragments, globose productid brachiopods, lingulid atrypid and rhynchonellid brachiopods; low spired gastropods, bivalves and crinoid debris. Coral fauna (thamnoporids, solitary rugose corals) appear to be chiefly restricted to the upper 5 m of the Hare Indian Formation. Rare geopetal fills reflect paleoslopes of 5-20°.

(B) PALEOENVIRONMENTAL SYNTHESIS: The bituminous black shale lithofacies accumulated under relatively quiet, anoxic conditions following the termination of Hume carbonate deposition. The coarsening-upward nature of the Hare Indian Formation (calcisiltite lithofacies dominant towards top of sequence), increase in faunal diversity, and transition from medium-green shales into pyritiferous dark-grey shales reflect shallowing upward conditions. Thus the depositional setting for the Hare Indian Formation was a gradually shallowing slope environment.

The presence of extensive nodular bedding, pyritized bedding tops, sharply diminshed fossil abundance and diversity, and decreased evidence of bioturbation in the uppermost 15 m of the Hare Indian Formation indicate a slowdown in sedimentary carbonate accumulation under slightly anoxic (restricted?) conditions and the development of submarine discontinuities. The timing, genesis and nature of these discontinuities are unclear at present. However, they may have served in the establishment of firm substrates for the development of Ramparts biostromes.

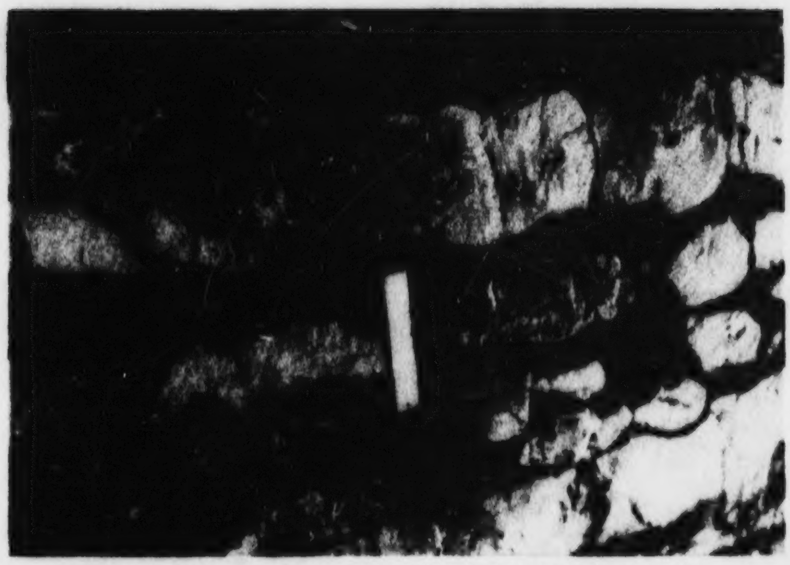

FIGURE 4: Calcareous mudstone-shale lithofacies abruptly overlying nodular calcisiltite lithofacies in the upper member of the Hare Indian Formation. Scale=15 cm, section 01, unit 017.

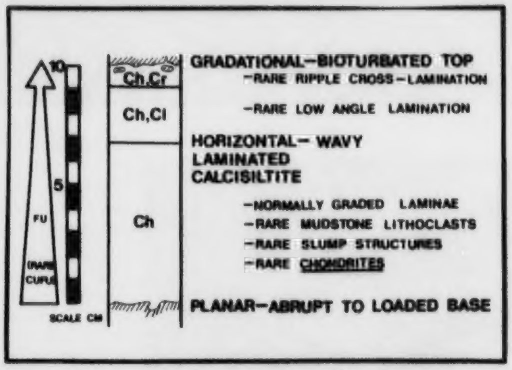
10
5
FU
(RARE
CUFU)
SCALE CM
Ch,Cr
Ch,Cl
Ch
GRADATIONAL–BIOTURBATED TOP
–RARE RIPPLE CROSS–LAMINATION
–RARE LOW ANGLE LAMINATION
HORIZONTAL– WAVY LAMINATED CALCISILTITE
–NORMALLY GRADED LAMINAE
–RARE MUDSTONE LITHOCLASTS
–RARE SLUMP STRUCTURES
–RARE CHONDRITES
PLANAR–ABRUPT TO LOADED BASE

FIGURE 5: Summary diagram of sedimentary structures obsreved in the calcisiltite lithofacies, Hare Indian Formation

RAMPARTS FORMATION

The Ramparts Formation is a Givetian limestone unit (Braun, 1978; Uyeno, 1978) that can be divided into two informal members (Tassonyi, 1969). The lower well-bedded "platform" member is gradational with the Hare Indian Formation (Fig. 6) and is characterized by the presence of interbedded argillaceous limestones and shales. This sequence thickens markedly westward, from 19 m at West Powell Creek to 29 m at Bell Creek. The "reef" member abruptly overlies the "platform" member and similarly thickens from 70 m at section 04 to 220 m at Bell Creek.

In a quarry exposure at Norman Wells, truncation of reef-flat sediments in the uppermost beds of the "reef" member implies lithification prior to the deposition of the overlying Canol Formation. However, there is no sedimentological evidence of prolonged subaerial exposure and the discontinuity is likely the result of submarine hardground development prior to deposition of basinal shales of the Canol Formation.

At Powell Creek, platform and reef-derived sediments of the Ramparts Formation are abruptly overlain by a 22 m-thick chert-bearing carbonate sand sequence of E. Frasnian age ("Allochthonous Beds" in Uyeno, 1978; Braun, 1978; Aitken, Cook and Yorath, 1982). The upper contact is gradational with the Canol Formation shales. Detailed conodont sampling has been conducted to ascertain if there are any significant faunal breaks in the Ramparts Formation-Canol Formation sequence.

(A) LITHOFACIES GROUPS: the Ramparts Formation can be subdivided into informal groups on the basis of constituent lithofacies, colour, depositional texture, bedding and sedimentary structures, diagnostic fossils, and distribution. Wilson (1975) discussed similar groupings (standard facies belts) and his environmental interpretations provide the basis for the following division into lithofacies groups.

(i) Platform margin lithofacies group is gradational into the overlying open marine platform lithofacies group, and is 11 m thick at W. Powell Creek. The assemblage is dominated by medium-dark grey nodular-bedded calcisiltite mudstones and wackestones, mud shales, and mottled limestones (Fig. 7) with discrete "sausage"-shaped calcisiltite nodules. Fossils include Hexagonaria; tabular Alveolites; common solitary rugose corals; and rare atypical brachiopods, thamnoporids, Billingsastraea, Rensselandia, crinoidal debris and tabular stromatoporoids. Rarely preserved normally graded laminae, rotational slump faults, and slump folds indicate slope deposition. Selective early cementation of the platform margin lithofacies group is documented by the following features:

- prevalent nodular bedding style;
- mottled bedding, some discrete nodules show brecciation and shale infill (Fig. 8). These nodules commonly display darkened edges;
- preferential encrustation of 3 - 5 cm topographic highs on nodular bedding tops by tabulate corals;
- pyritiferous horizons tends to occur near bed tops.

ii) Open marine platform lithofacies group in the W. Powell Creek area (10 m thick) consist of thin to medium-bedded bituminous mudstones, packstones and floatstones. The following upward trends were observed in the assemblage, indicating the progradational, shallowing-upwards nature of the "platform" member:

- matrix becomes finer-grained and darker as rudstone-dominated units are succeeded by floatstone-dominated units;
- bedding thins and becomes more nodular, pyritized bed contacts becoming increasingly more abundant;
- average allochem size decreases;

FIGURE 6: (right) The well-bedded 'platform' member of the Ramparts Formation is abruptly overlain by the 'reef' member at section 03.

FIGURE 7: Mottled limestones within the platform-margin lithofacies group, Ramparts Formation. Scale is 15 cm long. Section 03, unit 016.

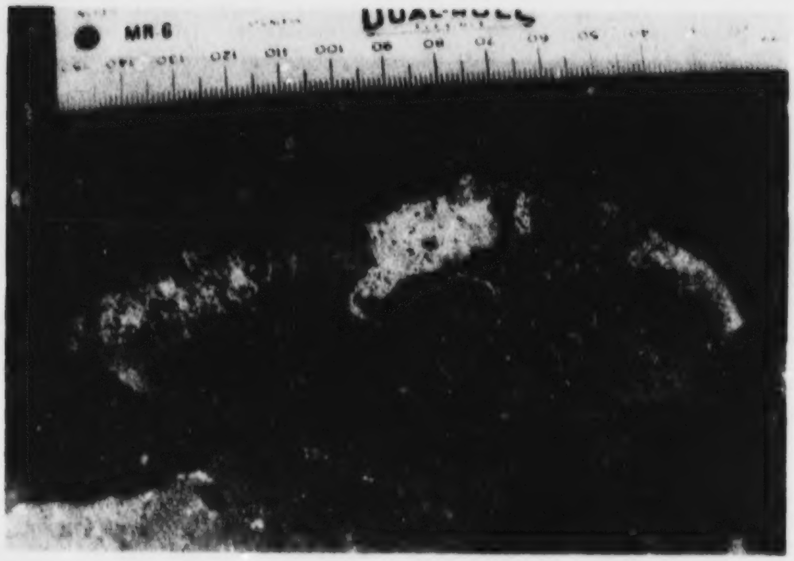

FIGURE 8: Calcisiltite nodule showing brecciation and shale infill. Platform-margin lithofacies group, Ramparts Formation at section 03, unit 015. Scale is in cm.

- biotic diversity decreases from the rudstones with Stringocephalus, Alveolites, thamnoporids, atrypid brachiopods, bulbous to tubular stromatoporoids, solitary rugose corals and crinoids to the floatstones dominated by branching-erect organisms (thamnoporids, solitary rugose corals) with rare crinoidal debris, atrypids and gastropods.

The uppermost 10 cm of the assemblage and "platform" member displays common, large (1-3 cm) pyrite nodules, and a microunconformable upper contact (5 cm relief).

(iii) Platform-reef transition lithofacies group abruptly overlies the open marine platform group in the W. Powell Creek area. In this vicinity, the platform-reef transition lithofacies group is a medium-bedded, light-medium brown, horizontally stratified unit that thins from section 03 (4.8 m thick), 800 m east to W. Powell Creek (0.6 m thick). The unit is composed primarily of grainstones. Geopetal fills in brachiopods indicate shallow depositional slopes (5-10^{0}). The upper contact of the unit is irregular and encrusted by tabular stromatoporoids. Allochems are current-oriented and commonly display micritized rims. Faunal elements include: abundant well-sorted brachiopod fragments, common crinoidal debris and rare bulbous stromatoporoids, Alveolites, sponge (?) fragments and thin tabular stromatoporoids. Disseminated iron oxide (after pyrite?) and, very rarely, rounded lithoclasts are present in the unit.

(iv) Back reef lithofacies group in the Powell Creek area is approximately 5 m thick at section 04 and gradationally overlies the reef margin-upper foreslope lithofacies group. The present erosional surface marks its upper contact. The sequence is dominated by texturally well-sorted thamnoporid-Amphipora-Stachyodes rudstones containing abraded, current-oriented, branching-form allochems. Extensive spar-reduced interparticle porosity characterizes the sediments where they are thickly interbedded with reef margin bindstone lithofacies. Nodular, thinly-bedded cherty mudstone beds occur rarely toward the top of the sequence.

(v) Reef margin-upper foreslope lithofacies group consists primarily of thickly-bedded to massive rudstones and bindstones. Faunal elements include in situ low-extended hemispherical-tabular stromatoporoids (Fig. 9), thin wafer stromatoporoids (possibly serving to stabilize framework by encrustation and overgrowth), and robust branching Stachyodes and thamnoporid fragments. The medium-brown rudstone matrix is commonly stylolitized.

(vi) Middle foreslope lithofacies group is made up of medium- to dark-grey, medium-bedded, thin wafer stromatoporoid-Stachyodes rudstones and floatstones. Bed contacts are commonly encrusted by tabular stromatoporoids. Rarely, very thin (3-5 cm) laminated beds of grey shale containing a styliolinid-tentaculitid fauna are interbedded with the limestone beds. Rarely, pyrite nodules are present near the limestone bed tops.

(vii) Lower foreslope lithofacies group consists of thinly bedded, horizontally laminated carbonaceous thin-wafer stromatoporoid floatstones and dark grey, fissile calcareous shale. Shale beds (3-5 cm thick) are stylolitized and compacted against the irregular nodular limestone beds. Several allochems display shale-infilled borings. Thin-wafer

FIGURE 9: Reef-margin-foreslope lithofacies group, Ramparts Formation. Note large, low-extended hemispherical stromatoporoids. Section 04, hammer is 35cm long.

FIGURE 10: Thin wafer stromatoporoids and thamnoporids in the lower foreslope lithofacies group. Note shelter porosity. Section 04, unit 003. Scale is 15 cm long.

stromatoporoids are up to 60 cm long and 1 cm thick (Fig. 10). Thamnoporids, crinoidal debris, atrypid brachiopods, Stachyodes, and tabular stromatoporoids are rare, and bulbous stromatoporoids are very rare. Both allochthonous and autochthonous biota are present and the average allochem size decreases from the middle foreslope lithofacies group.

(viii) Foreslope sand lithofacies group is present in the W. Powell Creek section where thickly bedded brachiopod-crinoid grainstones and thinly bedded normally-graded Amphipora rudstones overlie the basin margin lithofacies group. The foreslope sand lithofacies group is probably transitional to the basin margin sequence exposed at Powell Creek. Grainstone beds thicken upward and display stylolitized bed contacts, pervasive silica content, disseminated iron oxides and a low-diversity open marine faunal assemblage (including abundant fine-grained crinoidal debris, common smooth-shelled brachiopod fragments, rare abraded thin-wafer stromatoporoids). Amphipora rudstones cap the foreslope sand sequence exposed at W. Powell Creek and contain micritized allochems derived from shallower lithofacies of the reef complex (including algal-encrusted atrypid brachiopods, thamnoporids, tabular stromatoporoids, tabular Alveolites, crinoidal debris, solitary rugose corals and terebratuloid? brachiopods).

(ix) Basin margin lithofacies group includes debris flow and laminite facies. The debris flow units are thickly bedded, planar-lenticular floatstones and wackestones that are arranged in fining-upward sequences, reflecting deposition at gradually decreasing energy levels. Groove marks on the bed soles indicate a northwest off-reef source. Allochems are matrix-supported and the fabric is imbricate to chaotic. Basin margin debris flow lithofacies are exposed only at Powell Creek and contain a faunal assemblage suggestive of middle foreslope derivation (thin-wafer stromatoporoids, thamnoporids, stachyodes, Alveolites, atrypid brachiopods, crinoidal debris). The debris sheets show "pinch and swell" geometry and may be channelized and discontinuous along strike and thus not exposed at W. Powell Creek.

The basin margin laminates consist of thin planar-bedded calcilutites, calcisiltites, and medium-bedded, fining-upward bioclastic limestones (floatstones to wackestones). The mudstones typically display normally graded laminae. Contorted clastic dykes, truncation surfaces, slump folds, light sole-markings, and the development of early replacement chert, particularly in the "Allochthonous Beds", characterize the basin margin laminates. Faunal elements include styliolinids, rare crinoidal debris, and thin-shelled brachiopod fragments.

(B) PALEOENVIRONMENTAL SYNTHESIS: The Ramparts Formation in the Bell Creek-Powell Creek area accumulated during three major depositional cycles, followed by a post-reef modification phase:

1. Open marine platform depositional cycle: The open marine platform lithofacies group was initiated on a partly lithified substrate. Its progradational nature is indicated by the more restricted fauna, decreased bedding thickness, and increased shale content towards the platform top. The influx of terrigenous detritus and restricted anoxic conditions were terminated by deepening water and the development of a submarine hardground.

2. Reef Depositional Cycle 1: Following the drowning of the platform, a laterally discontinuous but extensive (greater than 2 km), thin (0.6-4.8 m thick) sand shoal was deposited under essentially open marine conditions. Local patch reefs were initiated in the Bell Creek area and coalesced upwards, extending laterally over forereef lithofacies groups as reef growth eventually outpaced sea level rise.

The final phase of reef development (cycle 1) indicates another acceleration in sea-level rise and retreat of the reef margin. There is some evidence of sediment-starved conditions with the patchy development of early cemented beds bounded by stylolitic horizons and iron-stained rubbly limestones at the top of the second depositional cycle exposed at section 05. The second depositional cycle is approximately 38 m thick at sections 03 and 04.

3. Reef Depositional Cycle 2: the third major depositional cycle during Ramparts time, shoaled upwards in response to decelerating sea-level rise. The sequence exposed at sections 04 and 05 is approximately 36 m thick.

It appears that the rate of reef progradation decreased as steepening primary dips in foreslope lithofacies can be observed in section 04. The aggradational style of reef depositional cycle 2 is in marked contrast to the reef progradation and retreating style of cycle 1 and the three depositional styles probably mark an overall transgressive sequence for the Ramparts Formation. More data are required to ascertain upper contact relationships with the Canol Formation.

4. Post-reef modification phase: The "Allochthonous Beds" (Uyeno, 1978; Braun, 1978) exposed at W. Powell Creek and Powell Creek (20-25 m thick) are charaterized by high chert content, a low-diversity faunal assemblage, abundant evidence for mass flow emplacement and rare megabreccia beds exposed at the top of the sequence. Derived sediments appear to have been mainly of slump origin or from slope failure of incoherent margin material rather than sediments derived from the mechanical erosion of a lithified buildup. This may indicate a rather insignificant hiatus between the Ramparts Formation and "Allochthonous Beds".

CANOL FORMATION

The Canol Formation is a Frasnian shale-dominated sequence that records widespread clastic deposition in the Norman Wells-Powell Creek area (Aitken, et al., 1982). The Canol-Ramparts contact is locally disconformable due to erosion of the upper reef complex units. The Canol Formation is absent or very thin in the Bell Creek area where the Imperial Formation overlies a thin (7 m thick) covered interval that in turn is underlain by the thickest accumulation of Ramparts (220 m thick) in the thesis area. In the Powell Crek section, the Canol Formation is approximately 23 m thick and is conformably overlain be a hematized, recessive shale unit of the Imperial Formation.

(A) LITHOFACIES:

(i) Black shale lithofacies consist of fissile, dark brown-grey siliceous shales which commonly show a distinctive yellow-green weathering colour and oil stains along parting planes. Silica content appears to be variable on a 1-3 cm basis and decreases towards the top of the sequence (increasingly recessive shales). Macrofossils are extremely rare and include styliolinids, fish fragments and pyritized brachiopod fragments. Caryorhynchus coquinas (3-5 cm thick) are present near the gradational interbedded basal contact of the Canol Formation. Strata display parallel horizontal laminae, probably as a result of episodic suspension sedimentation in still water. Minor lenticular to wavy stratification may indicate periodic traction transport. The black shale lithofacies show little evidence for wave mixing or bioturbation. The units are characterized by a very high mud-sand ratio, and pelagic styliolinid coquinas, documenting low sedimentation rates.

Large (long axis = 0.5-1.0 m) ellipsoidal calcareous concretions are confined to an approximately 7-m-thick unit in the Canol Formation (Fig. 11) and display poorly preserved, pyritiferous graded laminae.

(ii) Crinoidal grainstone lithofacies are thinly bedded units that commonly display normal grading and planar-abrupt to slightly erosional basal contacts marked by rare black shale and calci-siltite lithoclasts. The crinoidal grainstone lithofacies is a minor (less than 2%) constituent of the Canol Formation exposed at Powell Creek and is restricted to the basal 10 m of the sequence.

(B) PALEOENVIRONMENTAL SYNTHESIS: The major transgressive pulse that was associated with Ramparts Formation deposition may have initiated widespread anoxic conditions by means of an expanded oxygen-depleted, nutrient-enriched water layer. Clastic deposition may have occurred during standstill conditions at the close of the Givetian. However, Canol deposition may also have been the result of slow basinal shale sedimentation that was undiluted by carbonate accumulation and gradually onlapped the reef complex. As more normal marine conditions resumed, the Canol Formation was gradually overlain by the Imperial Formation.

IMPERIAL FORMATION:

The Frasnian-Famennian clastic sequence is approximately 460 m thick at Powell Creek (Mackenzie, 1970; Uyeno, 1978) and consists of interbedded siltstone, shale and sandstone with minor amounts of limestone and conglomerate (Aitken et al., 1982). The succession can be divided according to the following hierarchy:

1) Fining-upward (FU) cycles/coarsening-upward (CU) cycles; average thickness = 2-4 m.
2) CU cycles; average thickness = 20-35 m.
3) FU megasequences; average thickness = 90 m.

Stacked CU sequences in section 01 and FU megasequences in section 02 are attributed to allocyclic controls. However, more data will be required in next year's field season to ascertain their significance.

1. FU cycles are more prevalent in the upper, sandstone-dominated portion of the CU sequence. The depositional units display planar-abrupt to slightly erosional basal contacts. Thickly bedded, bioturbated fine-grained sandstones (Sm) pass upwards to medium-bedded, horizontally stratified sandstones (Sh) in a gradational interbedded manner. Thin discontinuous bioclastic lenses occupying shallow scours are more common towards the base of the cycle and faunal elements include: Billingsastraea; Regelia; abundant fish fragments, atrypid brachiopods and gastropods.

Sh shows rare normal graded laiminae, low-angle stratification, mudstone lithoclasts and primary current lineation. Sh lithofacies are gradationally interbedded and transitional into thinly bedded siltstone, mudstone lithofacies (Fl). The medium dark, green-gray Fl lithofacies are typically bioturbated with Chondrites, Planolites and Paleophycus trace fossils. Normally graded laminae, groove marks and climbing ripple lamination are rarely preserved. Brachiopod coquinas occur infrequently at the tops of cycles.

2. CU cycles tend to characterize the lower mudstone, siltstone-dominated portion of the CU sequences. The "nested" cycles thicken upwards with a corresponding increase in bedding thicknesses. Sedimentary structures and faunal elements are similar to those observed in the sandstone-dominated FU cycles.

Preliminary paleocurrent analyses indicate a northwest source. The sheet-like geometry of the sandstone bodies, sharp-planar to undulating erosive cycle bases, and extensive bioturbation of Fl lithofacies capping the FU cycles suggest a storm-dominated shelf environment for the Imperial Formation.

FIGURE 11: Limestone concretions within the black shale lithofacies, Canol Formation. Section 01, Powell Creek. Figure is 1.7 m high.

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Eskers in the Redrock Lake Region, NWT
A Possible Prospecting Tool

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ABSTRACT

In the Redrock Lake region (85G) in the Northwest Territories, meltwater flow from the last ice mass was concentrated along well-defined corridors. These "glaciofluvial corridors", which are spaced every 10 to 12 km, contain esker ridges, washed till, and minor ridges of ice-contact diamicton or poorly sorted bouldery gravel. Esker materials range from coarse sands to boulders 60-80 cm in diameter. Boulders are not distributed randomly within the esker sediments but commonly form the principal component of short esker segments averaging 10-30 m in length. These segments of extremely coarse open-work material recur every 1.5-2 km along some eskers. Meltwater transported sediment to the glacier base along tunnels in the ice mass. Boulders carried by fast-moving water did not travel far along the esker tunnel, but were deposited as soon as the gradient flattened, i.e. when the water reached the main tunnel at the base of the ice. The finer gravel and coarse sand fractions were carried and deposited farther downstream. This interpretation of the grain size distribution implies that, although esker ridges may be continuous for several tens of kilometres, they may have been deposited as successive, comparatively short segments. If this model is an adequate reflection of reality, prospecting based on the study of esker material could substantially reduce the target area.

INTRODUCTION

The Redrock Lake (86G) region is east of Great Bear Lake and just west of Point Lake, Northwest Territories. The southern Coppermine River cuts across the northeast part of the map area (Fig. 1).

Glacial till is the most abundant unconsolidated sediment in the Redrock Lake region. Although it can be generally described as a diamicton composed of blocks and boulders in a silty sand matrix, its grain size varies from pebbles distributed in a silty sand matrix to accumulations of openwork boulders. Two classes of till are recognized: a till blanket with average thickness in excess of 2 m that effectively masks all traces of underlying bedrock; and a till veneer, generally less than 2 m thick, which is composed of bouldery material distributed as irregular patches mostly in the western and northern part of the area. To the east and to the south of Scotstoun Lake, the till has been moulded into drumlin fields (Fig. 1).

Glaciolacustrine silt, deltaic bouldery gravel and alluvial sand are confined to Coppermine River Valley between Redrock Lake and Hepburn River (Fig. 1).

GLACIOFLUVIAL CORRIDORS

The melting of glacial ice produced enormous amounts of water that entrained englacial and subglacial sediments, which were redeposited as outwash gravel and sand. These powerful meltwater streams not only deposited sediments, they washed corridors free of all but the largest boulders. In these glaciofluvial corridors, sections of bare bedrock alternate with ice contact features that include esker ridges, transverse and circular ridges, and minor morainic ridges (Fig. 2).

Glaciofluvial corridors occur at regular intervals; along a north-northeast to south-southwest transect, spacing averages 12-15 km (Fig. 1). They represent the beds of former major meltwater streams that had lost all their tributary streams as a result of the melting of the ice. The frequency of corridors indicates very high drainage density and the large size of the transported material implies powerful streams.

Esker ridges are the most prominent components of glaciofluvial corridors. These sinuous, steep-sided, sharp-crested ridges with an irregular crest profile are up to 30 m high, but more commonly are 10-20 m high. Although esker ridges may be continuous for 20 km or more, they are far from being homogenous in composition.

Esker material ranges from coarse sand to boulders 60-80 cm in diameter (Fig. 3). Boulders are not distributed randomly through the esker material but form the principal component of short esker segments averaging 10-30 m in length. These segments of extremely coarse openwork structure or diakene sediments (Lundqvist, 1979, p. 10) commonly occur at regular intervals of 1.5-2 km. It is likely that boulders did not travel far along the esker tunnel. Carried by fast-moving water flowing down steeply dipping ice tunnels, they were deposited as soon as the gradient flattened i.e. when the water reached the main tunnel at the base of the ice. Gravel and coarse sand were deposited downstream (Fig. 4). The interpretation of grain-size distribution implies that, although esker ridges may be continuous for several tens of kilometres, they are in fact constructed of successive, comparatively small segments.

Flat-topped terraces, commonly fan-shaped, typically occur along eskers (Fig. 2 and 4). These outwash terraces were formed when meltwater was no longer confined to an ice tunnel and flowed into the open at the margin of the ice (St-Onge et al., 1981, p. 329). They mark an ice front position and occur at intervals of approximately 1.5 to 5 km along most eskers (Fig. 2 and 4). The time interval associated with these phases has not been determined.

Numerous minor landforms are associated with eskers in glaciofluvial corridors. Two will be described in some detail: a circular ridge of bouldery gravel and ridges of boulders, gravel, and sand transverse to corridor alignment (Fig. 2).

Figure 5 is an oblique low-level air photograph of an oval ridge of outwash cobbles and coarse gravel. The form is 140 m long and approximately 70 m wide. It occurs at the western end of a glaciofluvial corridor just east of Acasta River (Fig. 1). The long axis of this oval ridge has an azimuth of 10 degrees. Elevation of the ridge above the central depression varies between 7 and 11 m. Interior and exterior slopes are in the 25-30 degree

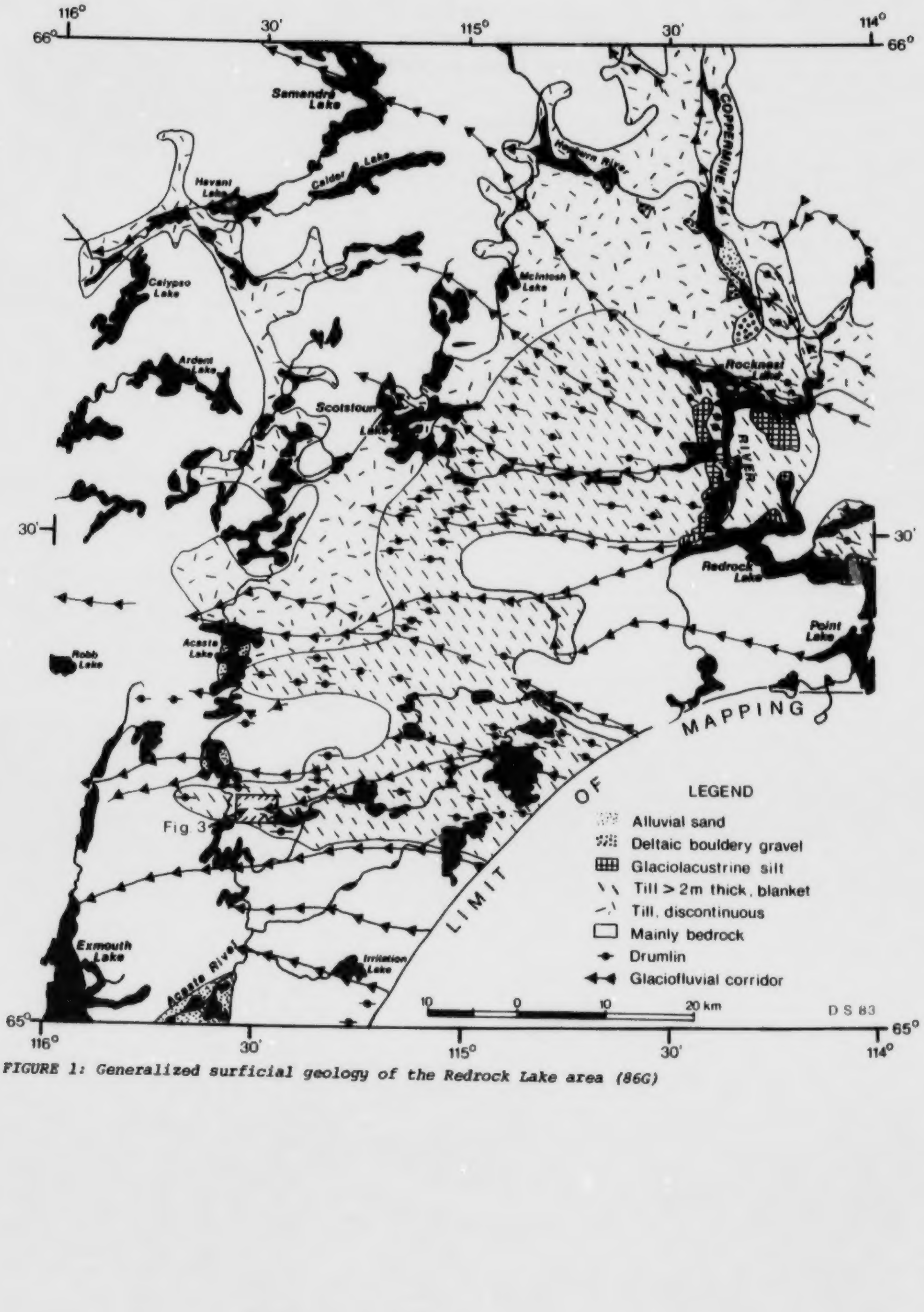

FIGURE 1: Generalized surficial geology of the Redrock Lake area (86G)

FIGURE 2: Stereogram of glaciofluvial corridor and associated landforms. E-esker ridge, Et-esker terrace, Gr-gravel and sand, O-oval ridge, Br-bedrock, R-minor ridges. Note well-developed drumlins (D) typical of Irritation Lake drumlin field. (NAPL A11532-135,136)

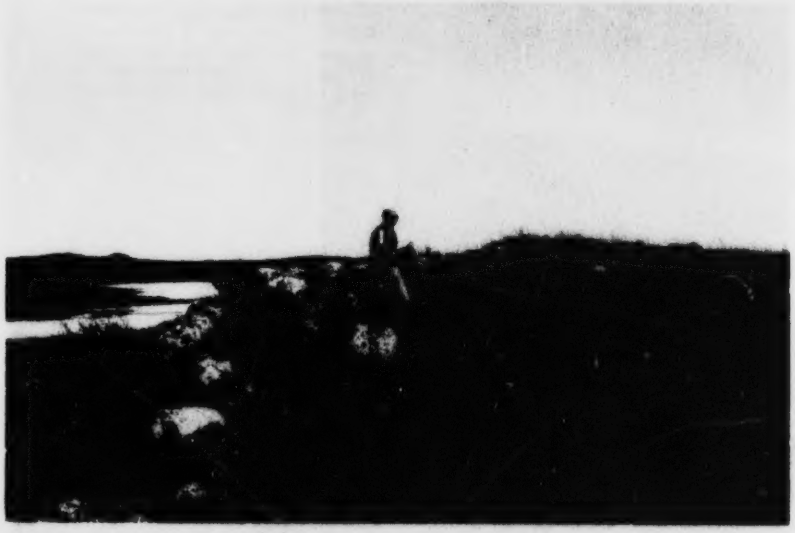

FIGURE 3: Extremely bouldery segment of the esker ridge found in the central part of figure 2.

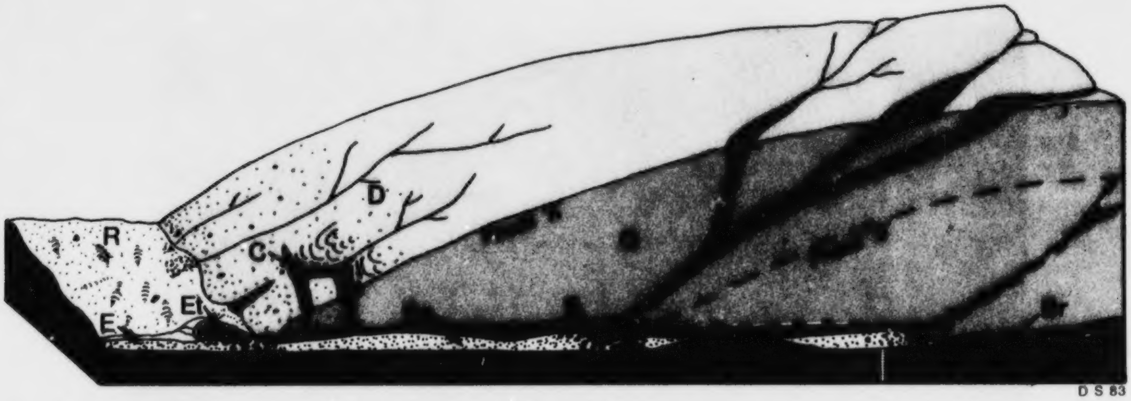

FIGURE 4: Origin of sediments and associated landforms along a glaciofluvial corridor. Note that during phase B the constricted flow above a bedrock knob prevents sedimentation; this will result in a "washed surface". E-esker, Et-esker terrace, Gr-gravel and sand, B-boulders, R-ridges, C-crevasses, D-debris, G-glacier ice, T-tunnel, Br-bedrock.

FIGURE 5: Low-level oblique airphoto of an oval ridge of outwash cobbles, gravel and sand; view is south-east. Notice bedrock outcrop in the east and west and the small esker to the south-southeast of the ridge (downstream)

range. The northern crest rises 17 m above the surrounding bedrock, which is partly covered by a thin veneer of till and sandy gravel. A small esker ridge of bouldery gravel extends southwest from the oval ridge and climbs partway up the east-facing side of a bedrock hill. To the east (upstream) is another small esker 4-5 m high composed of boulders 30-50 cm in diameter. Similar forms have been described by Lundqvist (1979, p. 27) who speculated that these "circular eskers" were formed by the "filling of subglacial channels or crevasses." However, since he does not describe the material of these forms it is difficult to make any direct comparison.

The oval ridge is part of an outwash complex deposited by a high velocity stream. This is demonstrated by the coarseness of the material of both the esker and the ridge as well as the presence of washed bedrock to the west (downstream). The ridge likely formed by rapid sedimentation around an ice block that had collapsed from the ice tunnel roof. Although this local widening reduced stream velocity to allow sedimentation of cobbles and of coarse gravel, downstream flow was still sufficiently constricted to nearly completely preclude sedimentation - hence the bare bedrock of the surrounding area, which is typical of glaciofluvial corridors.

Minor ridges of bouldery gravel or diamicton occur within the glaciofluvial corridors and generally are aligned at right angles to them (Fig. 6). The ridges occur in swarms 0.5-1 km wide and up to 10 km, long but more commonly 3-5 km long. Individual ridges are generally 1-5 m high, 10-80 m long, and 10-30 m wide; a typical ridge would be 3 m high, 30 m long, and 20 m wide, with slopes of 10-15 degrees. The material, which is always coarse, varies from openwork boulder structure to blocks in a sandy gravel matrix.

In places "tails" of well-sorted sand are found on the downstream (westerly) side of the small ridges. These features have not been found outside glaciofluvial corridors.

The upland surface on which the ridges are located precludes the possibility of formation in contact with glacial lake water, thus they are not genetically related to cross-valley moraines which they resemble (Andrews, 1963). More likely they result from the filling of crevasses and other depressions near the front of a downwasting ice mass (Fig. 4). Sediment flows on the ice surface would transport material towards crevasses that opened largely as the result of the collapse of the ice tunnel near the glacial front. As pointed out by Lawson (1981), the nature of sediment flows on a glacier is varied and depends on the amount of water involved. The material of the transverse ridges ranging from diamicton to gravel is a result of this complex sedimentation process.

A MODEL FOR PROSPECTING FROM ESKERS

Given the origin proposed above for the construction of eskers in short segments, the following question is pertinent: How would rocks and other materials derived from an ore body crossed by a glaciofluvial corridor be distributed in the eskers? It can be assumed that material eroded from the ore body by the overriding ice would be carried near the base of the glacier and would be dispersed laterally (Fig. 7A) and upwards. Once the ice started melting, water would concentrate this material in the tunnels in which eskers were being built. Therefore the ore body material should occur in the esker downstream of the ore body in diminishing quantities. The concentration would depend on the size and the amount of

FIGURE 6: Small ridges in a glaciofluvial corridor. Meltwater flow was generally from left (east) to right (west). Note figure for scale. Bouldery ridges, 1 to 5 m high, are aligned transverse to meltwater flow. Tails of well-sorted sand parallel meltwater flow and commonly occur on the downslope side of a bouldery transverse ridge.

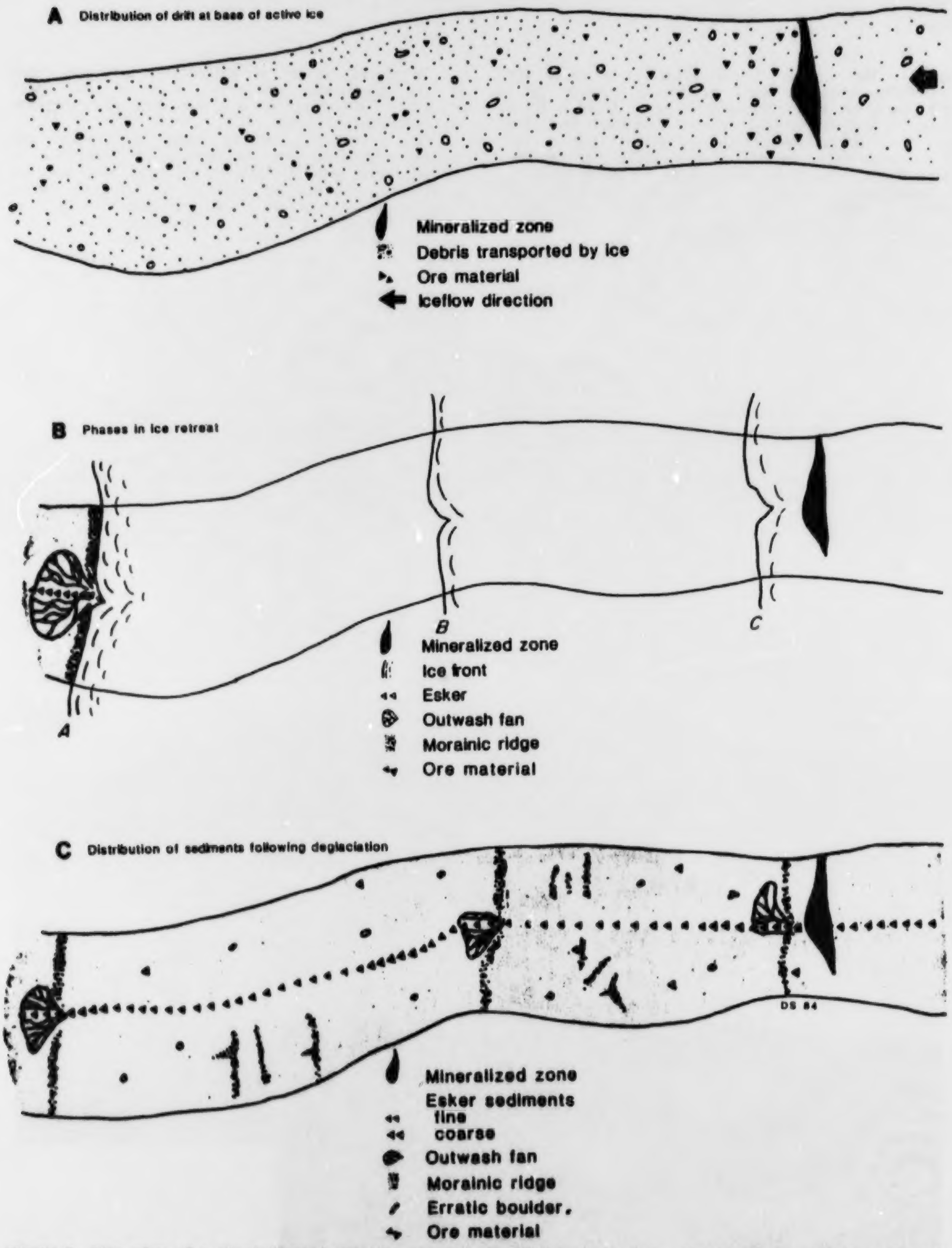

FIGURE 7: Plan view of a glaciofluvial corridor across a hypothetical ore body. The ice-front positions shown in B correspond to phases of ice retreat illustrated in Figure 4, and the esker fans are comparable to the esker terraces in Figure 2.

debris that the ice had plucked from the ore body. Concentration would decrease rapidly in a downstream direction; in the vicinity of the ore body it should be very high immediately down ice and it would be nil up ice. Because coarse material, in the cobble to boulder range, travels the least distance in an esker system, a concentration of this size of ore material would be a good indication of the proximity of a source area.

If the esker-building model presented here is applicable, then prospecting along eskers should be simplified, particularly if the ore material is represented by the coarser size fraction. In this case, the coarse material could be sampled until ore debris is no longer encountered. This would substantially reduce the target area. If mineral tracing has to be done through sampling of the sand fraction, then it is likely that the ore material will be found in longer segments of the esker downstream from the ore body.

This model, developed from walking on many eskers in the Redrock Lake area, has not been tested as a prospecting tool. It is presented here in the hope that it will simplify prospecting particularly in those regions that are generally heavily blanketed by unconsolidated deposits.

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STRUCTURE AND METAMORPHISM OF THE KESKARRAH BAY AREA
POINT LAKE, N.W.T.
SECOND PRELIMINARY REPORT

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INTRODUCTION

Archean rocks in the Keskarrah Bay area consist of a basement terrain and a supracrustal sequence known as the Yellowknife Supergroup (Henderson, 1975; Henderson and Easton, 1977; Bostock, 1980). The basement terrain (Henderson and Easton, 1977; and Easton et al 1981,1982) consists of two distinct lithologies; a complex heterogeneous gneiss terrain and a large body of fractured and chloritized granodiorite. Krogh and Gibbins (1978) have obtained ages of circa 2730 and 2600 Ma for the gneisses and 3155 Ma for the granodiorite. Overlying the basement terrain wih angular unconformity are rocks of the Yellowknife Supergroup, a sequence composed predominantly of graywacke-mudstone with minor mafic and felsic volcanics and conglomerate, probably deposited about 2680 Ma ago (Henderson, 1981). The contact between the lowermost unit of the Yellowknife Supergroup and the basement gneisses is locally well exposed, elsewhere age relationships are obscured by faulting, complex infolding, and granitic intrusion.

Of the three phases of deformation that affected the basement gneiss terrain, two can be traced into the supracrustals. The first phase, D_{1-x} formed a gneissic layering. During D_1 this layering was folded about F_1 fold axes, which correlate with F_{1-} in the supracrustals. The major deformation that affected the entire supracrustal sequence during D_2 only marginally overprinted earlier structures within the basement terrain, resulting in large- and small-scale F_2 folds.

Four phases of deformation are recorded in the supracrustal terrain. The first two (D_1,D_2) resulted in macroscopic folds (F_1,F_2) and an associated axial-plane cleavage (S_1,S_2). The third and fourth events (D_3,D_4) were mainly fabric-forming events (S_3,S_4).

Peak metamorphic conditions of middle to upper amphibolite grade were attained in the basement terrain during the gneiss-forming event, probably about 2700 to 2750 Ma ago. This was accompanied locally by migmatization and cataclasis. Later deformation at lower grades formed biotite and chlorite.

The Yellowknife Supergroup supracrustals were metamorphosed during a single event of progressive regional metamorphism at about 2650 Ma with grades ranging from greenschist to middle amphibolite. Mineral assemblages in the graywacke-mudstone turbidites indicate that metamorphic grade increases from greenschist facies in the west-central area to amphibolite facies towards both east and west; isograds trend approximately north-south. Exposures of the western amphibolite-facies terrain contain cordierite-andalusite(?)-bearing assemblages, while sillimanite is recorded in the eastern area.

Mapping in the summer of 1982 was concentrated in the western map area, within the gneiss terrain, and in the northern and eastern exposures of the Yellowknife Supergroup. Mapping in 1981 was concentrated in the central map area. This documented the deformational sequence within the gneisses and supracrustals, aided in the description of the gneiss-supracrustal contact and further delineated isograds in the pelitic rock units. This report summarizes the findings of the 1982 field season and incorporates the results of the 1981 mapping.

GENERAL GEOLOGY

Rock types in the Keskarrah Bay area are described by Henderson and Easton (1977), Bostock (1980) and Jackson (1981).

Supracrustal Terrain

Most of the area is underlain by supracrustals of the Yellowknife Supergroup (Figure 1), including minor volcanics of the Point Lake Formation (Bostock, 1980). 'Banded' mafic volcanics (unit 3) lie at the base of the cover sequence, probably unconformably overlying the gneissic basement (Easton et al, 1981), and possibly approximating the position of the original basin margin (Henderson, 1981). The unit forms a thin, northerly trending, linear belt in the central part of the area, but is complexly infolded with the gneisses to the north and south where small synformal infolds of unit 3 occur within the gneisses up to 1 kilometre west of the main supracrustal contact. Primary bedding features and preserved lapilli led Bostock (1980) to propose a tuffaceous origin for the unit. Unit 3 may be a lateral equivalent of pillowed to massive basaltic flows (unit 4), and the two units interfinger south of the south shore of Point Lake and on the peninsula near "Tree Bay" on the north arm of Point Lake. The basaltic flow unit may locally nonconformably overlie the basement granodiorite. Felsic volcanics (units 5 and 6) are thought to interdigitate with the mafic volcanics and may be lateral, basinal equivalents of the marginal mafic volcanics. Exposures of dacite (unit 5) on the shore of Point Lake are brecciated with a garnet-magnetite matrix. Near this locality, elongate garnet-amphibole-rich clasts with felsic rims are set in a fine-grained, siliceous, biotite-rich matrix and may represent the volcanic conglomerate described by Henderson and Easton (1977). Rhyolite (unit 6) appears to be dominantly fragmental. Local carbonate-rich metasediments (unit 7) flank the felsic volcanic centre and are interbedded with rhyolite, Contwoyto Formation turbidite sediments and iron-formation (unit 9).

Sandstone and conglomerate of the Keskarrah Formation (unit 8) unconformably overlie the basement granodiorite and interfinger with both the mafic flow unit and Contwoyto Formation sediments.

The Contwoyto and Itchen Formations (units 9 and 10), which comprise a graywacke-mudstone turbidite succession, are the most areally extensive units and provide much of the evidence for the structural sequence and metamorphic analysis.

Stratigraphic relationships between the mafic volcanics of the Point Lake Formation and the western 'belt' of the Contwoyto Formation turbidites were examined. This 'belt' of Contwoyto Formation turbidites probably underlies the 'banded' mafic volcanics

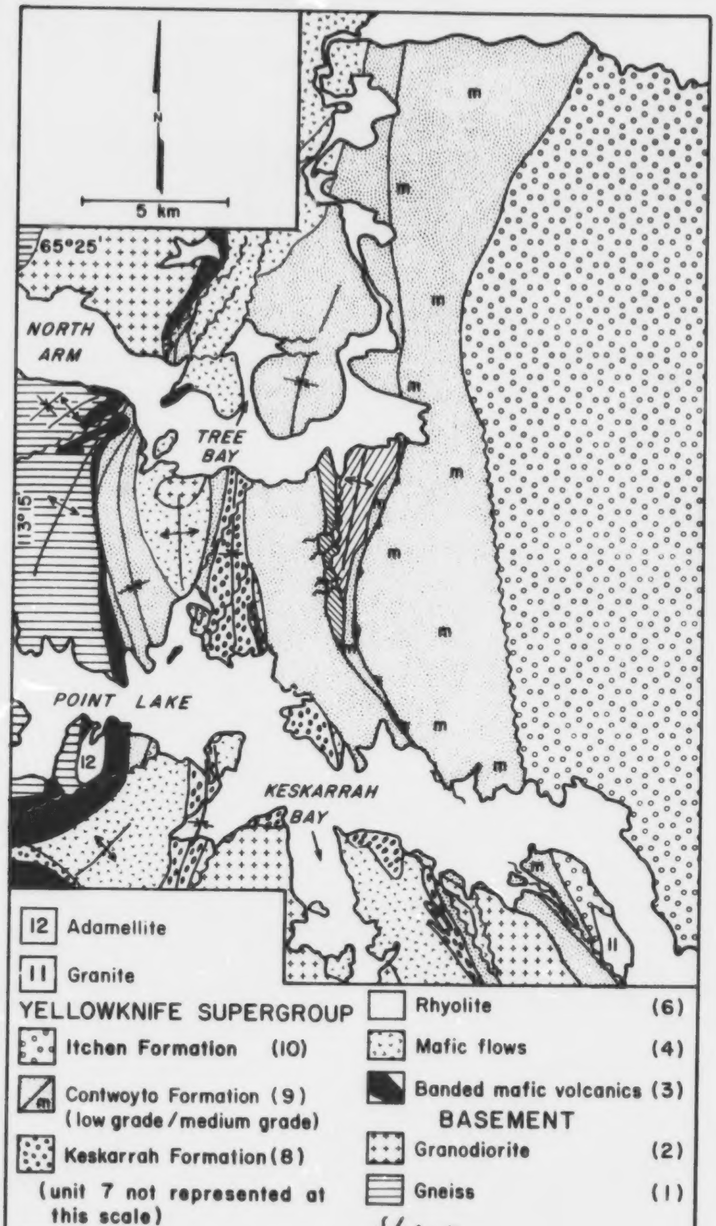

FIGURE 1: Geological map of the Keskarrah Bay area, parts of N.T.S. 86H/6,7. A detailed (1:25,000 scale) map of this area is available from the Northern Affairs Program as E.G.S. 1982-4 (1 map, $5.00)

(unit 3) and the mafic flows (unit 4) (Henderson and Easton, 1977), but contact relations are ambiguous. Where the contact between the metasediments and unit 3 is exposed, the former are strongly deformed and bedding facing directions cannot be determined. The metasediments are tightly folded in the region of the contact with unit 4 and the volcanics are typically highly altered, sheared equivalents of what may be massive flows. In one locality there are indications that the metasediments underlie the basic flow volcanics. Elsewhere the apparent stratigraphic order supports the basic conclusion of Henderson and Easton (1977).

The western 'belt' of Contwoyto sediments outlined by Henderson and Easton (1977) has been traced to the north, across the north arm of Point Lake (Figure 1). In this area also, stratigraphic relationships are complicated by tight folding and faulting.

Basement Gneiss Terrain

The western map area is underlain by a variety of gneisses (unit 1) considered to be basement to the Yellowknife Supergroup (Henderson and Easton, 1977; Easton et al, 1981, 1982; Henderson, 1981). They are described by Easton et al (1982). Hornblende-biotite tonalite to granodiorite orthogneiss is the most widespread unit. Other phases include; pelitic gneiss, granitic gneiss, and a thinly layered mixed gneiss unit consisting of hornblende-biotite tonalite, amphibolite, hornblende gneiss, and biotite-quartz-feldspar gneiss with granitic gneiss layers. Mapping of individual units within the gneiss terrain is complicated by abundant intrusive phases, some of which may represent partial melts of the gneisses. Intrusive pegmatite and granite are in part related to an extensive granitoid terrain to the west (Pointless Batholith; Easton et al, 1981) and in part related to the adamellite body (Henderson and Easton, 1977) that intrudes along the gneiss-supracrustal boundary.

Shallow, east-dipping granitic "sheets" are abundant within the gneisses on the large island in Point Lake and on both the north and south shores of the lake. These sheets have been intruded parallel to the gneissic layering and are deformed. The sheets increase in abundance toward the adamellite pluton (unit 12) on the south shore of the lake, suggesting a genetic relationship between the two. The pluton itself may also have intruded in a sheet-like manner (Easton, pers. comm., 1982). The adamellite intrudes both the gneisses and the 'banded' mafic volcanic unit of the supracrustal sequence, obviously post-dating the deposition of the Yellowknife Supergroup. Strongly deformed granitic material, presumably derived from unit 12, is found within the mylonite zone marking the gneiss-supracrustal contact, and abundant cataclastic granite is found to the west, adjacent to this contact. Intrusion of the adamellite pluton thus pre-dates the latest deformation within the mylonite zone. Intrusion of the granitic sheets related to the pluton pre-dates the last phase of deformation (D_2) that affected the gneiss terrain.

Amphibolite is abundant within the gneisses immediately west of the mylonitic contact with the 'banded' mafic volcanics (unit 3) and in the core of the antiform outlined by unit 3. The outcrops are discontinuous and restricted to the area adjacent to the mafic volcanics and may be correlative with them. The presence of small synformal infolds of mafic volcanics in the gneisses, which are recognized as belonging to the Yellowknife Supergroup sequence, supports this correlation. Some of the amphibolite may represent feeders to the volcanic pile (Easton et al, 1981, 1982).

STRUCTURE

At least one phase of deformation (D_{1-x}) affected the basement gneiss terrain prior to deformation of the supracrustals. This event formed gneissic banding. The recognition of gneissic cobbles in the Keskarrah Formation conglomerate that are lithologically comparable to units within the gneiss terrain (Easton et al., 1981, 1982), indicates that this gneiss-forming event pre-dates the deposition of the Yellowknife Supergroup.

The first phase of deformation (D_1) to affect both the gneiss and supracrustal terrains resulted in east-trending upright to shallow east-plunging F_1 folds. Structural trends within the gneisses and Pointless Batholith are easterly along the west margin of the map area. East-trending F_1 folds are preserved largely in the western exposures of the Yellowknife Supergroup, along the basin margin. The east-striking S_1 axial plane cleavage is the dominant fabric in western exposures of the 'banded' mafic volcanic, mafic flow unit and Contwoyto Formation. S_1 and F_1 are, however, refolded by second-phase folds. Farther into the basinal succession to the east, structures associated with D_1 are scarce and rarely observed within the medium-grade metaturbidites.

The second phase of deformation (D_2) formed a north-trending regional foliation (S_2) and north-trending F_2 axial traces. In the basement terrain this phase of deformation resulted in an overprinting of D_2 structures on easterly D_1 structures; east trending gneissic layering and upright minor folds are folded about the larger-scale F_2 antiform and synform. A weak S_2 axial plane cleavage is developed in the gneisses. West-verging recumbent folds, with shallow north-plunging fold axes and mineral lineations, were formed locally during D_2. These shallow, east-dipping structures steepen into the mylonite zone marking the gneiss-supracrustal contact.

In western exposures of the Yellowknife Supergroup, F_2 folds refold east-trending F_1 folds. A large-scale interference pattern, similar to type 3 of Ramsay (1967), is produced along the northwest margin of the supracrustals (overprinting of D_1 structures by D_2 structures is observed in this western area). Progressing eastward into the supracrustal basin, D_2 structures dominate. F_2 folds are seen to fold S_1 and bedding (S_0) with opposing facing directions, and in outcrop and thin section the S_2 regional foliation is dominant. F_2 folds are steeply to vertically plunging with steep north-trending axial planes. The dominance of steep easterly dipping limbs indicates westward overturning of the folds.

The third and fourth phases of deformation (D_3, D_4) were fabric-forming events and have only been recorded in the turbidite units (Contwoyto and Itchen Formations) of the supracrustal terrain. Evidence of D_3 is scanty in the Keskarrah Bay area, but is defined as a schistosity (S_3) which is developed locally in the eastern exposures of the sillimanite-grade Itchen Formation. S_3 is a southeast-trending, penetrative biotite schistosity that becomes increasingly more penetrative at higher metamorphic grades to the east in the eastern Point

Lake area; King, 1981.

At low metamorphic grades D_4 is represented by small-scale, variably-spaced crenulations (F_4) of S_2, with axial planes oriented at a high angle to S_2. At higher grades the F_4 axial plane is defined by the alignment of biotite porphyroblasts, which also appear to be elongated down-dip of S_2. At sillimanite grade a penetrative, northeast- to east-trending S_4 schistosity is developed at a high angle to S_2. Locally, S_4 is seen to have cross-cut S_3 and to have rotated cordierite porphyroblasts that have overgrown the S_3 fabric.

The observed orientations of structures related to the four phases of deformation suggest that each successive phase of deformation has an essentially orthogonal relationship to the event preceding it; east-trending structures of D_1 produced meridional stresses; north-trending D_2 structures formed in response to longitudinal stresses; the southeast-trending S_3 foliation was a consequence of northeast-trending stresses operative during D_3; and meridional stresses were again operative during D_4.

From west to east within the map area, there is a progressive increase in relative intensity of successive phases of deformation (Figure 2) such that: i) structures associated with D_1 dominate along the basin margin; ii) D_2 partly overprinted the basement gneiss terrain and refolded D_1 structures in the western exposures of the Yellowknife Supergroup, with only a weak S_2 axial plane cleavage developed, whereas further east D_2 structures dominate and S_2 is penetrative and forms the regional foliation; iii) D_4 is of lesser intensity than D_2 at lower grades and results in crenulation of the S_2 schistosity, but of an equal intensity to D_2 at higher grades to the east, leading to the development of an S_4 schistosity; iv) D_3 was a minor event in the Keskarrah Bay area with the S_3 fabric developed locally along the eastern margin of the map area, but is well developed futher east (King, 1981). The progressive increases in relative intensities of deformational events is coincident with the increase in metamorphic grade of the supracrustals (Figure 2), as is also noted in the eastern Point Lake area (King, 1981).

METAMORPHISM

The isograds mapped during the 1981 field season have been modified as a result of petrographic study and mapping during 1982. Within the Contwoyto Formation, throughout most of the map area, cordierite appears prior to the formation of andalusite in the paragenetic sequence. This relationship was also observed in the eastern Point Lake area (King, 1981). Cordierite has overgrown bedding and all tectonic fabrics except possibly S_4. The cordierite isograd is truncated by the Fubar Fault and felsic volcanics in the central map area (Figure 3). The cordierite zone is narrow compared to the andalusite and sillimanite zones. A large irregular and ill-defined area within the andalusite zone, in the central map area, may contain cordierite-bearing rocks without andalusite. The absence of andalusite in this area may reflect a differing bulk composition of the pelites.

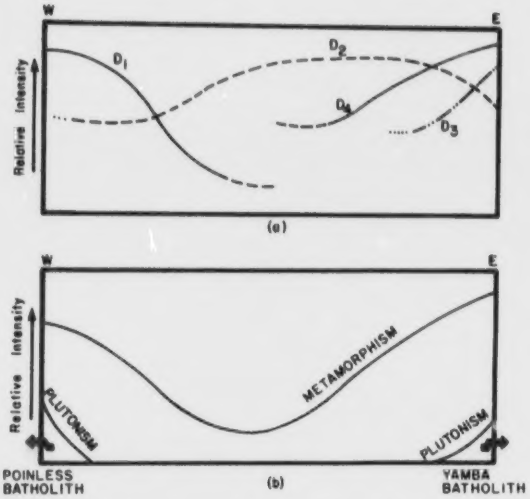

FIGURE 2: Metamorphism and deformation in the Keskarrah Bay area. 2a: Relative intensities of deformation. 2b: Relationship of metamorphism to plutonism.

Staurolite and more commonly garnet are present in the metaturbidites of the Contwoyto Formation in proximity to meta-iron-formation lenses. Such lenses may be 70% garnet. Garnet is not widespread in the meta-turbidites, and is restricted to the sediments adjacent to the iron formation. Its presence there reflects the Fe-rich bulk composition of the sediments rather than a higher pressure metamorphism. Staurolite however, occurs in the Contwoyto Formation where iron-formation has not been observed and within the Itchen Formation, which also lacks iron-formation. In these rocks, and in some of those associated with iron-formation, staurolite is found as relics in the cores of cordierite and less commonly in andalusite. Muscovite is either present in low abundances or as a late retrograde phase in these rocks. Staurolite can be attributed to a slightly iron-rich bulk composition of the pelites. Staurolite and cordierite do not commonly coexist (Winkler, 1976). Thompson (1978) gives two possible explanations that allow the coexistence of staurolite and cordierite (and/or andalusite) in these rocks: 1) The P-T space is small between a) the staurolite-consuming reaction and b) the reaction leading to the consumption of chlorite (reaction b follows a), such that the reactants, staurolite and chlorite, could still be present in the rock when andalusite and cordierite are formed, or 2) metamorphism is rapid, essentially 'freezing-in' the lower grade assemblages. In this manner, staurolite would be rimmed by cordierite and/or andalusite, as observed in the Contwoyto and Itchen Formations. These textures would reflect lower grades of the same metamorphic event that produced cordierite, rather than an earlier period of higher pressure metamorphism.

Sillimanite first appears within the Contwoyto Formation rocks in southern exposures. The sillimanite isograd cuts across bedding/foliation trends in both the southern and northernmost areas of the pelitic units (Figure 3). In the central area the isograd is coincident with the fault that locally

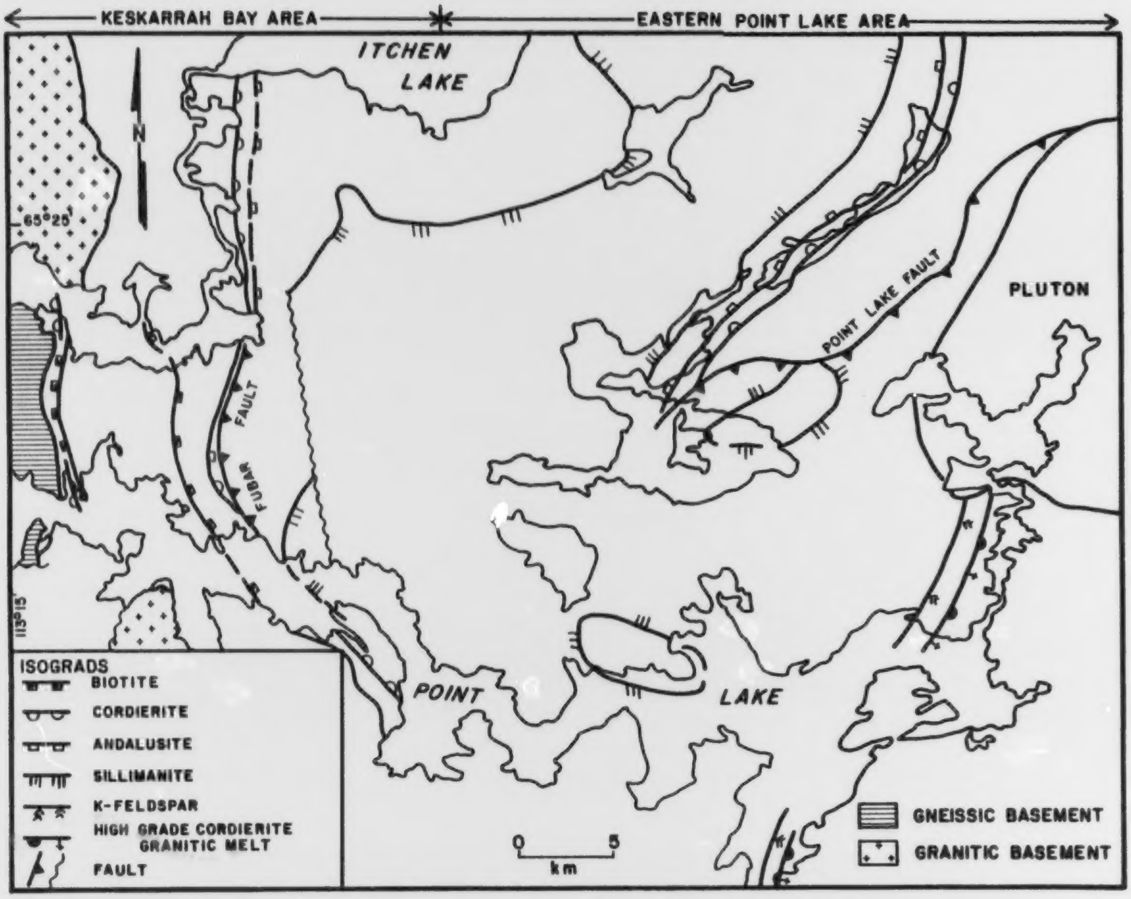

FIGURE 3: Distribution of metamorphic isograds in the Keskarrah Bay area (this study) and the Eastern Point Lake area (King, 1981). Isograds are defined only within the turbidite units.

marks the Contwoyto-Itchen contact. This isograd has been mapped to the east by King (1981; Figure 3). Small 'pockets' of andalusite-zone rocks are found within the sillimanite-grade metasediments, supporting the concept of shallow undulating isotherms (King, 1981).

The metamorphic grade of the supracrustals, recorded in the graywacke-mudstone turbidites, increases to the east and west from a low that approximately underlies the central exposures of the mafic flows (unit 4) and the Keskarrah Formation conglomerate (unit 8; Figure 3). The eastward increase in metamorphic grade is well documented in the Keskarrah Bay area by a progression of diagnostic mineral assemblages; from chlorite-muscovite to the first appearance of biotite; cordierite, generally accompanied by the absence of chlorite; andalusite; and finally sillimanite. This progressive increase in grade continues into the eastern Point Lake area (Figure 3) where the second cordierite isograd (coexistence of cordierite-K-feldspar-sillimanite) and first appearance of granitic melt mark the highest metamorphic grades attained and result in the metaturbidites being transformed into gneisses adjacent to the Yamba Batholith. Metamorphic conditions in this area were characterized by relatively constant low pressures and shallow undulating isotherms that culminated in a thermal dome in the area now occupied by the batholith (King, 1981).

The westward increase in metamorphic grade in the Keskarrah Bay area is less well documented because of the presence of the gneiss terrain and abundant retrograde mineralogies in the supracrustal rocks. However, metamorphic mineral assemblages in the Contwoyto Formation turbidites indicate a westward increase in grade from chlorite-muscovite to biotite assemblages, to cordierite and possibly andalusite-bearing assemblages. This westward increase in grade may be related to emplacement of the Pointless Batholith to the west. If this is the case, the higher-grade metamorphic terrains may be related, directly or indirectly, to the granitoid batholiths, to which they show a spatial proximity.

DISCUSSION

A preliminary, and tentative, correlation between the four phases of deformation (D_1 to D_4) that affected the supracrustal terrain of the Keskarrah Bay area and those deformations recorded in the eastern Point Lake area (King, 1981) are summarized in Table 1. In both areas D_1 resulted in east-trending isoclinal F_1 folds. In the western Keskarrah Bay area a penetrative S_1 axial plane cleavage is associated wiih F_1 folds, while in eastern exposures of the metaturbidites D_1 structures are not well preserved. In the eastern Point Lake area, D_1 resulted in F_1 folds without an associated cleavage. Fabric development is associated with D_1 in western exposures of the Point Lake supracrustal belt, but not in eastern exposures. Similarly, during D_2, regional F_2 folds in the Keskarrah Bay area are associated with an S_2 foliation, but those in the eastern Point Lake area are not. The orientation of regional second-phase folds differs between the two areas (see Table 1).

The main differences in D_1 structural characteristics between the two areas may be a reflection of the basement gneiss terrain in the Keskarrah Bay area. Along the west margin of the belt, the Yellowknife cover sequence appears to have been isoclinally infolded with the basement gneisses during D_1. It is likely that the relatively incompetent supracrustals, folded into synformal 'keels', within a relatively competent gneiss terrain, would have been more prevasively deformed than the supracrustals in the main part of the basin. Thus, the Yellowknife supracrustals along the basin margin developed a penetrative cleavage while those within the basin did not.

The difference in style and orientation of main-phase F_2 folds, and the presence or absence of an associated axial plane cleavage, may be related to the basement terrain in the Keskarrah Bay area and to the position of the Yamba Batholith. The Point Lake supracrustal belt forms an arc that is concave to the southeast. Lithologic contacts, F_2 axial traces and fan axes (defined in the eastern Point Lake area; King, 1981) conform to the arcuate outline of the belt, which appears to be wrapped around the Yamba Batholith. This relationship suggests that D_2 may be related to emplacement of the batholith. The east-northeast trend of structures and lithologies in the eastern Point Lake area swing to a northerly orientation in the Keskarrah Bay area.

F_2 folds in the Keskarrah Bay area are overturned toward the basin margin and the basement gneiss terrain is only locally overprinted by these main-phase folds. This suggests that the basement terrain may have acted as a buttress against which the supracrustals were deformed. Deformation of the supracrustals would have been more intense closer to the basement buttress, as in the Keskarrah Bay area, than away from it, as in the eastern Point Lake area.

Both D_3 and D_4 are present in the Keskarrah Bay and eastern Point Lake areas and have similar characteristics. S_3 is not widespread in the Keskarrah Bay area or in western exposures of the eastern Point Lake area, but it is the dominant foliation throughout the eastern exposures of the medium- to high-grade turbidites in the eastern Point Lake area. S_4 is recognized in the central exposures of the medium-grade Contwoyto Formation in the Keskarrah Bay area and becomes more pronounced toward the east, and is the dominant fabric in the western exposures of the low- to medium-grade Itchen

TABLE 1: CORRELATION OF DEFORMATIONAL EVENTS, SUPRACRUSTAL TERRAINS, KESKARRAH BAY/E. POINT LAKE AREAS

	D_1	D_2	D_3	D_4
KESKARRAH BAY	F_1: E-W bedding, fold axes and axial plane orientations. Isoclinal folds.	F_2: Major-phase folds. N-S trends of bedding, axial planes and some fold axes. Tight and steeply plunging to vertical and overturned to the west.	No major folding	No major folding. Crenulation of S_2 foliation. Biotite lineation in low to medium-grade Contwoyto Formation.
	S_1: E-trending, steeply dipping, penetrative axial plane cleavage in western exposures. Chl-biot-musc-(cord/and?) associated w/ D_1	S_2: penetrative regional foliation in central and eastern exposures. Chl-biot-musc associated with D_2.	S_3: SE-trending foliation in eastern exposures of the Itchen Formation.	S_4: Biotite schistosity in medium-grade Contwoyto Formation and Itchen Formation. Easterly trends.
EASTERN POINT LAKE	F_1: E-W bedding, fold axes and axial plane trends.	F_2: Major-phase folds. North of Point Lake Fault: upright to overturned with horizontal plunges. South of Point Lake Fault: upright to steeply reclined and isoclinal. Moderate south plunges.	No major folding. Small-scale folding of quartz veins.	No major folding. strong axial plane crenulation cleavage. Warps F_2 in high-grade terrain. F_4 steeply plunging and folds S_0 and F_2 axial traces.
	No associated penetrative fabric or metamorphic mineral growth.	No associated penetrative fabric or metamorphic mineral growth.	S_3: Regional foliation (140-160° trend) dominant in medium to high-grade (gneissic) Itchen Formation	S_4: Regional (010-060° trend) dominant in low to medium-grade Itchen Formation.

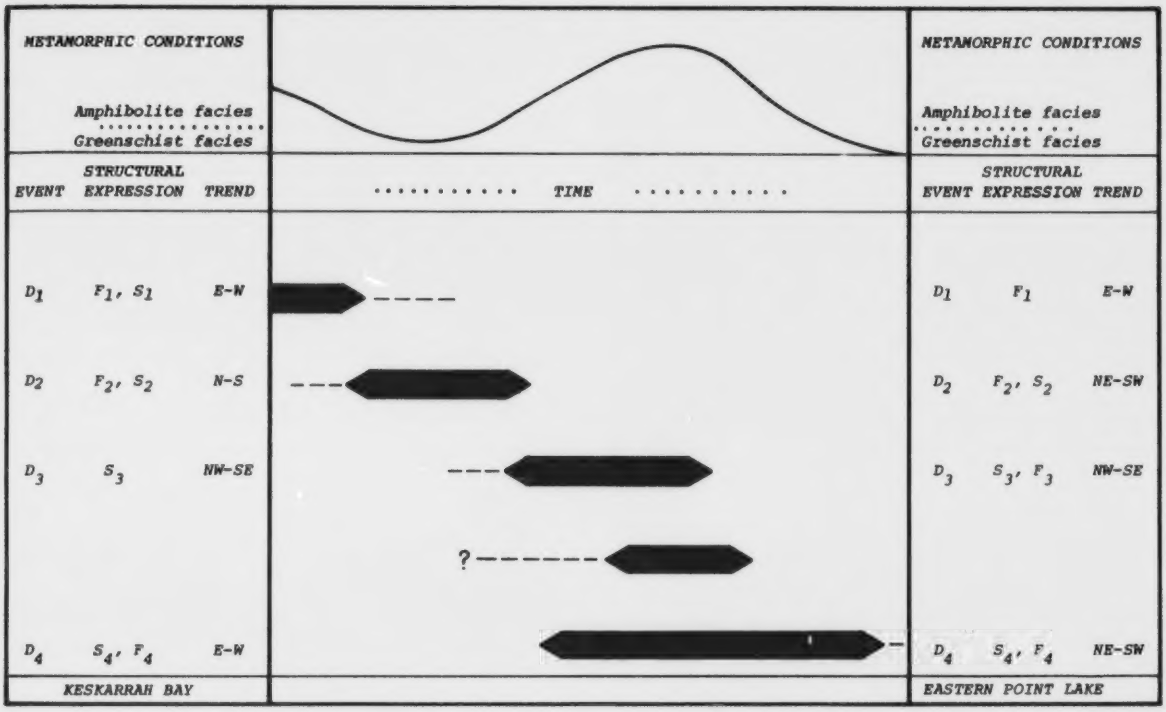

FIGURE 4: Correlation of metamorphic events, structural expressions and structural trends between the Keskarrah Bay area (this study) and the eastern Point Lake area (King, 1981)

Formation of the eastern Point Lake area.

The relative timing of metamorphism and deformation in the Keskarrah Bay and eastern Point Lake areas is summarized in Figure 4. In general all deformation was prior to or during peak metamorphic conditions. Metamorphic mineral growth during D_1 and D_2 is recorded only in the Keskarrah Bay area. D_1 occurred during and slightly before metamorphism peaked in western exposures of the Contwoyto Formation, where biotite, muscovite and chlorite are aligned in the S_1 cleavage plane, but cordierite/andalusite (?) porphyroblasts have overgrown S_1. In western exposures, D_2 post-dates porphyroblastic growth. In central exposures, D_2 occurred during the onset of metamorphism as indicated by the orientation of biotite, muscovite and chlorite in the S_2 plane, but cordierite and andalusite overgrow this fabric. Thus, metamorphism outlasted D_2. In the Keskarrah Bay area, D_4 for the most part pre-dates peak conditions, but it outlasted metamorphism in the eastern Point Lake area, as evidenced by a retrograde mineral fabric and the rotation of cordierite porphyroblasts containing the S_3 fabric (King, 1981).

The westward increase in metamorphic grade, documented in the Keskarrah Bay area, remains somewhat of an enigma, as the Contwoyto Formation sediments are at a higher grade than the underlying mafic flow unit (Figure 5). There are several possible explanations for this anomaly: 1) the sediments underlie the volcanics; 2) the stratigraphy is overturned, and 3) metamorphism in western exposures, and delineated isograds, are not related to the eastern regional metamorphic event. These possibilities have been examined, but available data is insufficient to be conclusive. Stratigraphic relationships along the sediment-volcanic contact are complex, and insufficient data are available on the effects of this metamorphism on the gneiss terrain. The third explanation is reasonable provided that the increase in grade can be related to the Pointless Batholith.

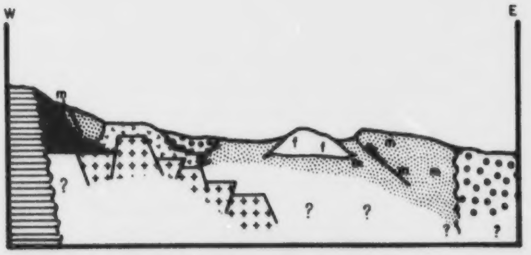

FIGURE 5: Schematic cross-section through the central Keskarrah Bay area. Symbols are shown on Figure 1. f = felsic volcanic center (rhyolite and dacite)

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Contributions to the geology of the Northwest Territories
Volume 1, 1984, I.N.A.C. EGS 1984-6, p. 55-62

FACIES ANALYSIS OF A MIDDLE DEVONIAN SEQUENCE IN THE MOUNTAIN RIVER-GAYNA RIVER

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INTRODUCTION

Field studies in 1983 were conducted in the Gayna River-Mountain River area along the Mackenzie Mountain Front (65°18'N, 129°21'W - 65°14'N, 128°35'W) approximately 110 km west of Norman Wells, NWT (Figs 1 and 2). Eighteen sections totalling 1300 m thickness were examined in a Middle Upper Devonian Sequence consisting of the Hume, Hare Indian, Ramparts, and Canol Formations. Lithofacies were grouped into facies associations that characterize the sequence in terms of distinctive depositional and biotopic conditions. These facies associations are based on general knowledge of recent carbonate sedimentation and comparison to ancient intracratonic clastic and carbonate depositional models.

STRATIGRAPHY AND SEDIMENTOLOGY

Devonian stratigraphy in the Mackenzie Mountains-Norman Wells area (Table 1 and Fig. 3) has been discussed by numerous authors (including Aitken, Cook and Yorath, 1982; Bassett, 1961; Braun, 1978; Pugh, 1983; Tassonyi, 1969). This report concerns the depositional environments, paleoecology and interrelationships of the facies associations making up the studied formations (Fig. 4).

DESCRIPTION AND INTERPRETATION OF FACIES ASSOCIATIONS

1: BASIN FACIES

Hare Indian Formation
- Bluefish Member
- lowermost beds of the upper member

The lithofacies composing the basin facies association within the Hare Indian Formation include bituminous, slightly calcareous laminated black shale, medium to dark-grey laminated shale, and grey laminated calcisiltite, some of which shows fibrous 'beef' structure. The predominance of even, parallel, horizontal laminae within the pyritiferous shale, and common pelagic styliolinid coquinas document low sedimentation rates under oxygen-depleted conditions with little or no wave mixing.

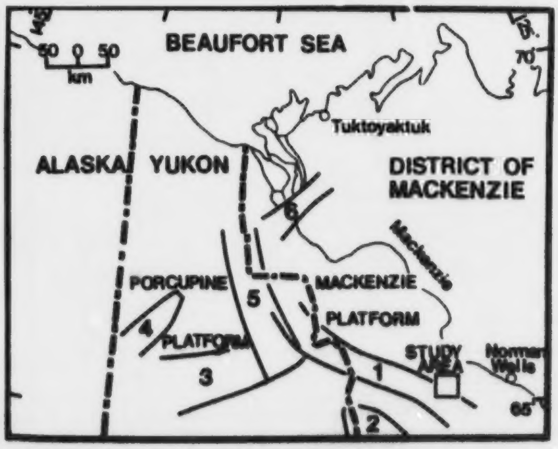

FIGURE 1: Locality plan showing the study area and Paleozoic tectonic elements. 1- Mackenzie Arch 2- Misty Bay Embayment 3- Blackstone Trough 4- Dave Lord High 5- Richardson Aulacogen 6- Aklavik Arch (Modified from Pugh, 1983)

The Hume - Hare Indian formational contact is planar-abrupt to slightly undulating. Rarely, wackestone nodules can be found approximately 0.5 m below the top of the Hume Formation. These have pyritiferous margins and septarian cracks with shale infill. The Hume platform was terminated during a relative rise in sea level by anoxic water. Tectonic uplift to the north and west resulted in progradation of clastic wedges onto a subsiding shelf (Tassonyi, 1969). Progressive deepening of the depocenter, possibly due to sediment loading, is indicated by the following:

(i) Plant fragments, bivalves, and inarticulate brachiopids are present in abundance only in the lower 5-10 m of basin facies association. Current alignment of allochems is common in lower portions, but rare in upper portions of the facies.
(ii) Shales are increasingly more fissile and bituminous toward the top of the Bluefish Member. Gradationally interbedded calcareous grey shale marks the close of anoxic conditions at the base of the upper member. This marks incipient basin-fill conditions and breakdown of the chemocline, possibly due to decreasing relative rise in sea level.

Canol Formation

Siliceous black shale, chert layers, concretions approximately concordant to bedding and, rarely, fine-grained, dark, thin-bedded calcisiltite and graded crinoidal grainstones characterize the assemblage. There is no evidence for benthonic carbonate

TABLE 1: STRATIGRAPHIC TABLE FOR MIDDLE-UPPER DEVONIAN STRATA IN THE STUDY AREA

UNCONFORMITY		
UPPER DEVONIAN	IMPERIAL FORMATION	shale, siltstone, sandstone
	CONFORMABLE CONTACT	
	CANOL FORMATION	shale; black, siliceous, bituminous
DISCONFORMITY ?		
MIDDLE DEVONIAN	RAMPARTS FORMATION	limestone, shale
	CONFORMABLE CONTACT	
	HARE INDIAN FORMATION	shale, limestone
	CONFORMABLE CONTACT	
	HUME FORMATION	limestone, shale

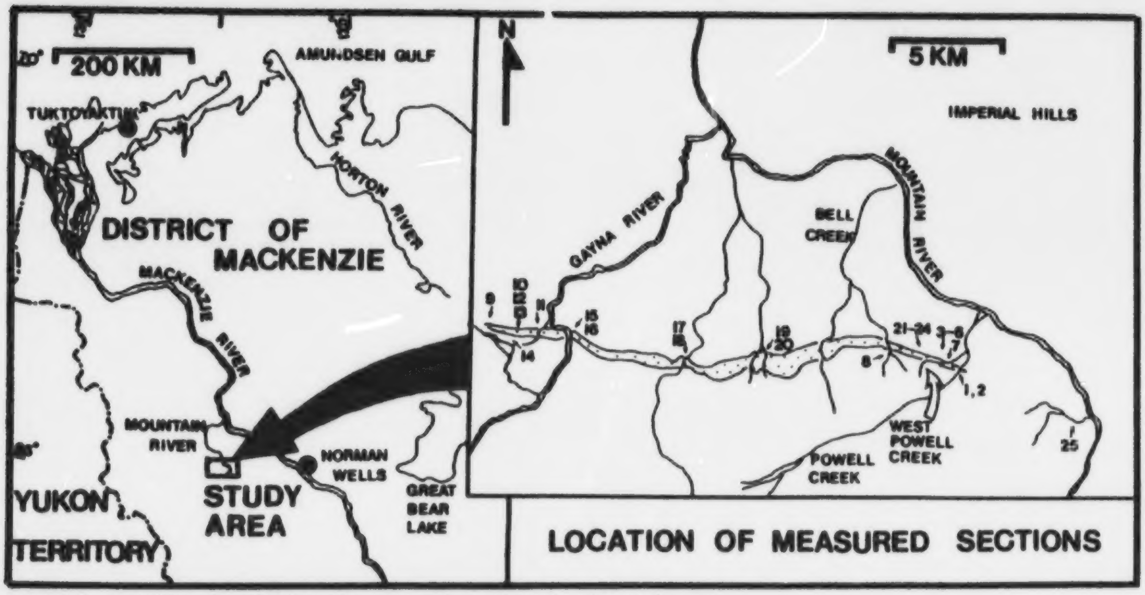

FIGURE 2: Locality plan showing the measured sections in the study area

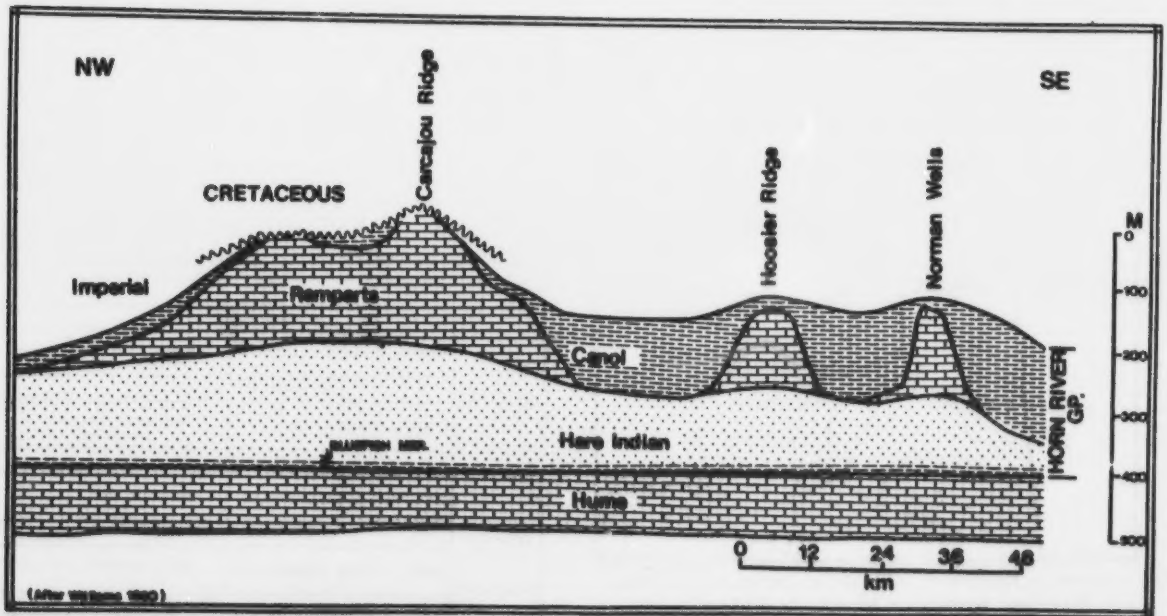

FIGURE 3: Distribution of Middle to Upper Devonian strata in the Mackenzie Platform area. (Modified from unpublished data of G. K. Williams, 1980)

production within the basin facies association, and planktonic and nektonic fauna (styliolinids and fish) are present only rarely.

Calcisiltite turbidites, graded crinoidal grainstones and slump structures, which are rare, imply differential off-reef relief during Canol deposition and may have been triggered by oversteepening as slope sediments accumulated above the calcite compensation depth (CCD). These units were deposited below the CCD, but were not affected by dissolution because of rapid emplacement and removal from contact with carbonate-undersaturated bottom waters.

Gradational interbedded contacts with the Ramparts Formation can be seen in reef cycle 2 (foreslope sands facies association, discussed in later section). Rarely, Canol-like shale lithoclasts and loose pyrite gossan were observed in backreef facies in section 20 at the top of the Ramparts Formation. However, the Canol-Ramparts contact may be locally disconformable due to marine erosion of upper reef complex units. There is no field evidence for subaerial exposure (eg. karst topography, caliche crusts, pisoids, beach rock, etc.) prior to onlap.

2: BASIN MARGIN FACIES

Hare Indian Formation
- Upper member

The basin margin-clinotherm sequence is dominated by a succession of greenish-grey shale, marl, and medium-grey calcisiltite lithofacies. Shale content increases and the shale darkens eastward to Mountain River (section 25) from West Powell Creek (section 7). Silt content increases as the Hare Indian Formation thickens westward from Bell Creek (section 8) to Gayna River (Figs. 4 and 5).

Slump structures, syndepositional folding and faulting, clastic dikes, rare geopetal fills and abundant load casts in the calcisiltite lithofacies within the lower units of the basin facies association indicate deposition on a clinoform surface.

Many of the calcisiltite units were emplaced as turbidites largely derived from the upper slope as indicated by the following features:

(i) - considerable lateral extent of beds.
(ii) - fining/thinning and coarsening/thickening trends in calcisiltite beds within thick units of alternating limestone and marl.
(iii) - poor sorting and high percentage of clay minerals.
(iv) - bed basal contacts commonly sharply defined to loaded; rare sole markings.
(v) - normal grading common.
(vi) - some beds that are not extensively bioturbated show sedimentary structures indicative of decelerating mass flow.

Increased carbonate/marl plus shale content, appearance of shallower water fauna including thamnoporid tabulate corals and solitary rugose corals, and the presence of fine-grained, quartzose tempestites in the uppermost 20 m of the basin margin facies association indicate shallowing to above storm wave base. Nodular bedding characterizes this portion of the facies association and appears to be determined by primary inhomogeneities such as bioclastic lags (coquinas) and burrows.

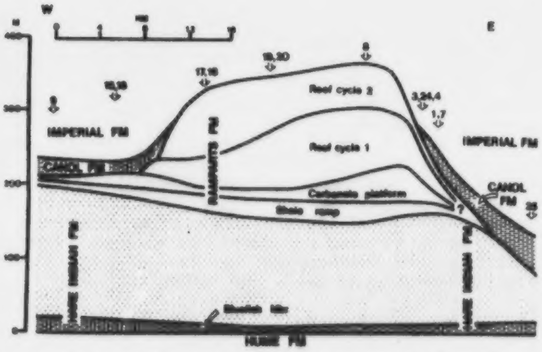

FIGURE 4: Distribution of facies associations in measured sections (numbers 1-25) within the study area. Vertical exaggeration = 65x

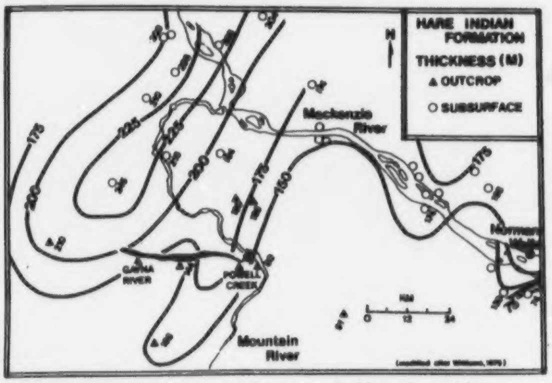

FIGURE 5; Thickness of the Hare Indian Formation within the study area (shaded area). (Modified from unpublished data of G.K. Williams, 1979).

3: TRANSITIONAL SHALE-RAMP FACIES

Ramparts Formation
- Lower member

The transitional shale ramp-basin margin facies assemblage is dominated by medium-dark, pyritiferous, grey nodular-bedded calcisiltite mudstone and wackestone, marl and mottled limestone.

The lower boundary is where carbonate beds predominate over shales in upward succession. However, the facies association is gradational both laterally and vertically with the underlying basin margin facies and overlying shale ramp facies. There is no apparent evidence for a sharp break in slope between these facies associations. The transitional shale ramp-basin margin assemblage lacks winnowed platform margin sands and displays rare rotational slump folds indicative of slope deposition.

The abundance of poorly sorted lithologies with low particle-to-mud ratio suggests deposition below normal wave base. Tempestite sequences are more common near paleotopographic highs on lobes of the

Hare Indian Formation (eg. sections 15-19, Figs. 2, 4). Bioclastic coquinas resulted from periodic storm wave action, stirring up and reworking bottom sediments in lags. Density current action is suggested by rarely observed hummocky cross-stratification, probably under the influence of oscillatory storm-wave surge below fair-weather wave base (Aigner, 1982). Low-relief irregular undulations on bases of calcisiltite beds, dominance of horizontal lamination, and rarely observed dewatering structures are suggestive of rapid deposition from turbidite-like flow induced by storm surge ebb currents.

The transitional shale ramp-basin facies association was characterized by widely fluctuating sedimentation rates in dysaerobic waters below normal wave base.

4: SHALE-RAMP FACIES

Ramparts Formation
- Lower member

The assemblage is distinctly more planar-bedded than the underlying transitional shale ramp-basin margin facies association. Progradation and shallowing of the shale ramp is indicated by the following observations.

(i) - increased carbonate bed thicknesses.
(ii) - increased faunal diversity and abundance (criniod-atrypid-brachiopod-dominated nodular mudstones and wackestones, Stringociphalus-Rensellandia-Alveolites-tabular stromatoporoid-thamnoporid-solitary rugose coral-dominated packstones, floatstones, and bindstones).
(iii) - increased allochem size and decreased mud content.

These trends occur upward stratigraphically in the shale ramp facies association.

Carbonate developed on the clinoform surface where there was appropriate water depth, wave energy, nutrient supply and light, and where conditions for carbonate fixation were optimal (James and Mountjoy, 1983). Decreased clastic input due to diminished source contribution or pulses of increased relative rise in sea level permitted carbonate production. At the same time, regressive outbuilding of carbonate ramp facies appears to have restricted water circulation in intraramp depressions. Evidence for increased restriction can be observed in the uppermost 1 m to 6 m of the shale ramp facies association, and this interval may be equivalent to the Carcajou Marker. Tassonyi (1969) noted that the argillaceous strata of the Carcajou Marker are unevenly distributed across the platform, and are absent from some sections in the Norman Wells area. He attributed the deposition of these facies to lagoonal conditions behind bioclastic accumulations. The Carcajou-like facies were deposited in broad depressions, and their constituent lithologies and thickness were determined mainly by pre-Carcajou surface relief and the position of the chemocline. The sequence thins eastward (section 7; 2.6 m thick), which in contrast contains the thinnest Hare Indian sequence in the study area.

With relative rise in sea level the shallow lagoons became more starved of sediment and relatively more euxenic as the topographic relief increased with time. A deepening trend for the lagoonal sediments is indicated by the following features:

(i) - matrix becomes finer grained and darker upwards. Bindstone- and rudstone-dominated units are succeeded by floatstone, calcisiltite and shale-dominated units.
(ii) - boitic diversity decreases. Sediment-shedding, branching-erect thamnoporids are more common towards the top of the Carcajou-like assemblage.
(iii)- average allochem size decreases.
(iv) - nodular limestone units thin towards the top of the shale ramp facies association with more abundant pyritized bed contacts and allochems.
(v) - tempestite sequences in sections 18 and 20 fine and thin upwards, reflecting waning storm surges and increasing protection from wave action. Hardgrounds are rare.

The shale ramp was probably terminated by accelerated sea level rise that promoted growth of a widespread carbonate-forming benthos. A discontinuity between the shale ramp and overlying carbonate platform is implied by the following observations.

(i) - There is a rapid transition upward from bituminous mud-supported lithologies to grain-supported, light-coloured lithologies. There is a marked change from thin nodular limestone beds into medium-thick planar beds of the carbonate platform. The uppermost 10 cm of the shale ramp at section 3 displays large (1-3 cm) pyrite nodules and possible hardgrounds (5 cm relief) within the uppermost limestone beds.
(ii) - The occurrence of fossil allochems indicates different ecological niches. Faunal diversity increases markedly above the shale ramp. Winnowed platform-edge grainstone includes abundant abraded brachiopod bioclasts, crinoidal debris and rare solitary rugose corals, thamnoporids, encrusting Alveolites , and robust-branching and thin-tabular stromatoporoids.

A reconnaissance section examined along the Mackenzie River indicates, however, a gradational contact between the shale ramp and carbonate platform. In any case, the discontinuity probably is minor in the study area.

5: PLATFORM MARGIN FACIES

Ramparts Formation
- Lower member

Winnowed platform-margin sands comprising well-sorted, crinoid-brachiopid grainstone and rudstone overlie the shale ramp association. The winnowed platform-margin sands (avg. 3-6 m thick) appear to represent shoals on topographically higher portions of the shale ramp (Fig. 4, top of Hume Formation as datum; sections 3, 21-24, 9-13). Biostromal units that abruptly overlie the shale ramp at sections 8 and 20 may be deeper water equivalents. The upper contact of the grainstone unit is commonly a hardground or is overlain sharply by a thin bituminous floatstone unit. Deepening may have resulted in a stable environment in which reef growth began.

6: RIMMED CARBONATE PLATFORM

Ramparts Formation
- Upper member

The open marine carbonate platform is characterized by an irregular, undulatory top. Its areal extent is marked by winnowed platform-margin sands. Alveolites -thamnoporid-tabular stromatoporoid buildups appear to be localized on pre-existing broad topographic highs (Fig. 4, top of Hume Formationas datum; sections 21-23, 12, 13, 15). Furthermore, bioherms are mainly restricted to the platform-margins, although basal biostromal units show upward biohermal tendencies.

The thickest accumulation of the facies association is a buildup (55 m thick) in section 23 near the eastern margin of the carbonate platform that may have controlled the inception of subsequent reef cycles. There is general westward thinning (Fig. 4, 10 m thick at section 9), although there appears to be little change from open marine conditions across the platform. The facies association is characterized by abundant rudstone, boundstone, and grainstone with less common floatstone, wackestone, and shale. The platform evolved above normal wave base under well-oxygenated conditions, although water energy was probably insufficient to remove arenite and volumetrically preponderant debris in areas around actively growing buildups (eg. section 21).

Platform lithofacies at Bell Creek (section 8) appear to have been deposited under deepening lagoonal conditions with crinoidal wackestone and shale becoming more abundant towards the top of the facies association. Turbid conditions within post-shale ramp depressions may have inhibited the less abundant fauna of low-level suspension feeders.

The rimmed carbonate platform initially possessed a stationary margin where carbonate accretion just kept pace with relative sea level rise. This platform-margin was initially delineated by the lobes of Hare Indian basin-fill sediment (Figs. 6,7). Sustained relative sea-level rise was such that sediments did build to sea level, and prograding tidal facies typical of peritidal carbonate platforms were precluded. Considerable relief was developed between the platform rim, deep-water foreslope and shelf lagoon, although the rim was never a continuous barrier restricting water circulation in the shelf lagoon (section 8).

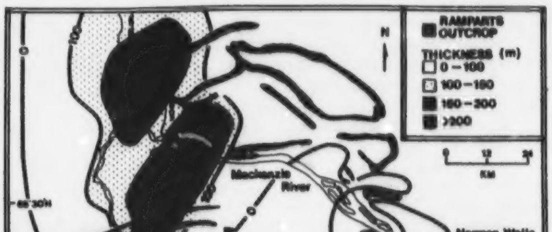

FIGURE 6: Distribution and thickness of the Ramparts (Kee Scarp) Formation in the study area. (Modified from unpublished data of G.K. Williams, 1979)

Destruction of the carbonate platform by accelerating sea level rise is inferred from the following field observations and interpretations:

- (i) - presence of hardgrounds and common pyrite along margin reef tops, indicating periods of nondeposition.
- (ii) - evolution of biostromal carbonate bodies into biohermal bodies within intrashelf depressions in response to accelerated rise in sea level. Foreslope limestones darken upward with increased shale content. Iron oxide-stained nodular and rubbly limestones cap the carbonate platform facies association at section 5.

The deeper marine lithofacies succeed shallow marine lithofacies in broad depressions on the shelf (eg. sections 20, 8, 6, 5, 3). This transition marks the incipient drowning event and the development of an onlap margin as sea level rise outpaced platform carbonate accretion (excepting platform rim reefs). At some stage in this development, conditions became optimal for the growth shelfward of reef cycle 1 (eg. accretional topographic highs).

7: RIMMED CARBONATE PLATFORM FORESLOPE

Ramparts Formation
- Upper member

The platform foreslope assemblage is present in sections 1, 7 and 9. The unstable nature of the carbonate platform-margin is reflected by 0.5 m to 1.0 m-thick debris-flow beds at Powell Creek. These units consist of allochthonous, platform-derived elements and are interbedded with shale and fine-grained nodular limestone. The debris-flow beds show matrix support of clasts, poor sorting, and basal tool marks indicating a derivation from the platform to the west. Chaotic fabric is common, although steep bioclast imbrication, seen rarely at bed tops, is possibly evidence of current action.

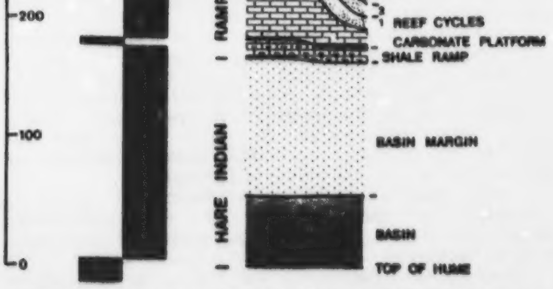

FIGURE 7: Deepening (D) and shallowing (S) trends in Middle-Upper Devonian strata within the study area.

The debris-flow units appear to have bypassed the margin, a common phenomenon on stationary platform-margins where relief between shelf/slope break and basin becomes progressively greater (James and Mountjoy, 1983). These mass-flow units were deposited below the lower limit of oxygenated water as indicated by pyritized bed tops and interbedded thin, dark nodular wackestone and mudstone.

8: REEF CYCLES 1, 2

Ramparts Formation
- Upper member

As previously mentioned, the thickest accumulation of carbonate platform facies are in buildups on the eastern margin of the shelf. These thick bioherms appear to have acted as topographic highs upon which reef cycle 1 was initiated. Both reef cycles 1 and 2 are characterized by framebuilt rims. These framework structures grew into the zone of turbulence, yielding abundant back-reef and fore-reef detritus. The reef cycles can be subdivided further into back-reef, reef margin-upper foreslope, lower foreslope and foreslope sand facies. However, as the study is in progress, only preliminary comparisons of the reef cycles will be made.

Reef cycle 1 (36 m thick in sections 4 and 5) shallowed in response to decelerating sea level rise (distal foreslope facies pass upward into reef flat facies). The rate of reef progradation apparently decreased, as steepening primary dips are present in foreslope facies in section 4. This final phase of reef development reflects another acceleration in sea level rise that finally terminated reef cycle 1.

Reef cycle 2 facies association has been mostly removed by present-day erosion along the eastern margin (section 24). However, a major backstep characterizes the inception of the depositional cycle as reef-margin boundstone abruptly overlies the reef-flat facies of reef cycle 1 (reef cycle 1 is 43 m thick approximately 400 m west of section 4). Encrusting and low-extended hemispherical stromatoporoids colonized a firm, possibly hard substrate. Horizontally stratified grainstone lenses are present rarely at the base of reef cycle 2 as dark-grey, high-extended hemispherical stomatoporoid-*Alveolites* boundstone passes upward into light grey-brown, tabular stromatoporoid boundstone with much spar-reduced interparticle porosity (total preserved thickness is 11 m in section 24). Reconnaissance traverses recorded thinning of reef margin-upper foreslope facies (200 m) eastward into lower foreslope lithofacies equivalents (thin, tabular, robust-branching-stromatoporoid boundstone, 8 m thick), although this thinning is, in part, a function of present-day erosion.

Field evidence suggests that more uniform environmental conditions were attained by the end of Ramparts time. Biostromal units characterized by robust-branching bulbous stromatoporoid framestone and rudstone make up the majority of reef cycle 2 back-reef facies in section 20, with rare fenestral laminite and *Amphipora* wackestone becoming subordinate towards the top of the Ramparts Formation.

Early cementation of the windward reef margin is indicated by the presence of foreslope-derived megaclasts within the foreslope sands (Allochthonous Beds of Mackenzie, 1970) at Powell Creek.

Reef cycle 2 represents the last stage of Ramparts carbonate deposition in this area. The reef complex was terminated by anoxic waters and burial beneath aggrading basinal Canol shales. Foreslope facies and the Canol Formation are gradationally interbedded at Powell Creek (section 1) and Mountain River (section 25). Canol-like extraclasts within back-reef facies were also observed at the Ramparts quarry exposure near Norman Wells.

During early Frasnian time, the chemocline broke down and basin fill was initiated by a relative drop in sea level and southeastward progradation of the Imperial Formation (sparse paleocurrent data). The capping Canol Formation is absent where the Ramparts Formation is thickest (eg. section 8), but this may be due to depositional thinning and submarine erosion by currents.

DISCUSSION

It should be noted that, although accelerating sea level rise terminated the Hume Formation and shale ramp, rimmed carbonate platform, and reef cycles 1 and 2 of the Ramparts Formation (Fig.7), it is not possible at present to elucidate the nature of the 'drowning' mechanisms. Furthermore, while the cyclic relative sea-level rises represent synchronous events, renewed carbonate production occurs more shelfward with each incremental rise. Thus the base of each facies association is diachronous as each sequence shoals upward. However, it does appear that the Ramparts Formation at Norman Wells shows similar shallowing-upward cycles and that the sequences were terminated by drowning events (J. Wendte, pers. comm.).

Perhaps each accelerating sea level rise was associated with some other stressing mechanism on carbonate production (eg. turbid anoxic waters or storm-introduced, fine-grained sediments). Inimical lagoonal waters of the shale ramp and rimmed carbonate platform may have proved inhospitable to carbonate-forming benthos and reduced their carbonate production with rising relative sea level.

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GEOLOGIE DU QUATERNAIRE DE LA REGION DE LA RIVIERE KENNARCTIC, DISTRICT DU MACKENZIE, TNO.

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RÉSUMÉ

La cartographie systématique des dépots meubles dans le secteur aval de la rivière Kennarctic au sud-est du golfe du Couronnement, T.N.O. permet de fixer les étapes de déglaciation, de fixer l'âge minimum du retrait des glaces à 10,000 ans B.P. et de définir l'importance de l'incursion marine postglaciaire à 200 m a.n.m.

ABSTRACT

Systematic mapping of surficial deposits in the lower reaches of the Kennarctic River, N.W.T. was carried out during the summer of 1982. As a result it has been possible to ascertain that, for the southeast part of Coronation Gulf, ice retreat occurred in four phases prior to 10,000 B.P., and that the postglacial sea covered land below 200 m a.s.l.

INTRODUCTION

La région étudiée se situe au sud du golfe du Couronnement, dans les Territoires du Nord-Ouest (fig. 1). Elle est délimitée par les latitudes 67°30' et 67°50'N et par les longitudes 110°30' et 111°00'O. Les travaux sur le terrain durant l'été 1982 ont permis la cartographie des dépôts meubles de la région de la rivière Kennarctic (carte E.G.S. 1982-6). La figure 2 définit les différentes unités retrouvées dans ce secteur. Celles-ci permettent de comprendre l'évolution géomorphologique du Post-glaciaire de cette partie du District du MacKenzie.

Le relief de la région est celui d'un plateau disséqué par de nombreuses vallées dont le tracé est contrôlé par la structure: la vallée de la rivière Kennarctic en est un exemple frappant (fig. 2). Ce plateau légèrment ondulé et incliné vers le nord varie entre 200 et 300 m d'altitude.

TRAVAUX ANTERIEURS

O'Neill (1924) a noté la présence au-dessous de 150 m d'altitude d'un important couvert de silt et d'argile marins tapissant les basses terres depuis la baie de Darnley jusqu'à la péninsule de Kent. Un énchantillon de coquillages cueilli par O'Neill à 97.5 m a.n.m. (fig. 1, site 2) et daté par Craig (1960) a donné un âge de 8290+330 B.P. (I-GSC-13)(tabl. 1). Ainsi le dernier inlandsis aurait libéré cette côte depuis au moins 8,300 ans.

Craig (1960) a observé égalment l'importance des sédiments marins le long de la côte du golfe du Couronnement. L'invasion marine a atteint, selon lui, la côte de 213 m a.n.m. à l'est du golfe du Couronnement. Il a découvert des fossiles marins à 85 m a.n.m. (fig. 1, site 1). L'âge radiométrique de ces fossiles est de 10,215+220 B.P. (I-GSC-17)(tabl. 1). Ainsi il stipule que la côte était libre de glace depuis au moins 10,000 ans.

Blake (1963) a étudié la géologie du Quaternaire de la région qui s'étend de la rivière Tree jusqu'à l'ouest du golfe de la Reine Maud (fig 1). Un till discontinu et plusiers erratiques du Wisconsinien supérieur sont présents à travers la région. Plusieurs stries indiquent un écoulement glaciare vers le nord-nord-ouest. Quelques crêtes morainiques marquent le front du glacier (fig. 1). Blake (1963) note en particular l'abondance des eskers ainsi que les kames et les deltas associés à ceux-ci.

Plusiers plages soulevées et d'importants dépôts de silt contenant des fossiles marquent la présence d'un niveau marin atteignant entre 198 et 213 m a.n.m. (Blake, 1963). Mais la mer ne pénétra pas très de la limite marine maximum à Bathurst Inlet donne un âge de 8370+100 B.P. (GSC-115)(tabl.1). La côte près de Bathurst Inlet était alors libre de glace il y a 8,4000 ans.

LES UNITES LITHOLOGIQUES

(a) La roche en place

La geologie de la roche en place de la région fut d'abord décrite par Fraser (1964). Une cartographie détaillée du secteur fut ultérieurement entreprise Easton et al (carte E.G.S. 1982-6) dans le cadre des travaux de l'été 1982. La région comprend des gneiss, des granites et des roches volcaniques du Précambrien. D'importants sills de diabase sillonnent le paysage.

(b) Les sédiments glaciaires

La roche en place est recouverte d'un till mince et discontinu souvent représenté uniquement par des blocs erratiques épars atteignant 4 m de diamètre. Seul dans le sud-ouest de la région retrouve-t-on un till entre 2 et 15 m d'épaisseur qui tapisse une dépression (fig. 2). Ce till est composé de blocs, de graviers, de cailloux dans une matrice de sable grossier. Aux rares endroits où elles peuvent être mesurées, les stries et les broutures indiquent un écoulement vers le nord-ouest.

Des sédiments de contact glaciaire se trouvent à l'est de la vallée de la rivière Kennarctic (fig. 2). Constitués de cailloux, de graviers et de quelques blocs anguleux ils forment des placages à la sortie de vallées parallèles au sens de l'écoulement glaciaire tel qu'indiqué par les stries. Ces vallées sont maintenant occupées par des ruisseaux intermittents qui s'écoulent vers la rivière Kennarctic. Les sédiments de contact glaciaire forment des crêtes légèrment bombées avec une pente raide vers la vallée de la rivière Kennarctic. Ils se sont probablement formés au contact du front glaciaire est d'un niveau marin plus élevé. La base de ces sédiments de contact glaciaire est un diamicton d'une dizaine de mètres d'épaisseur (fig. 2). Ce diamicton est composé de blocs, de cailloux et de gravier dans une matrice de silt et d'argile. Ce matériel peut s'être déposé directement dans un haut niveau marin depuis un front de glacier vêlant dans un bras de mer. Il s'agirait alors d'un "flow till" (Dreimanis, 1979).

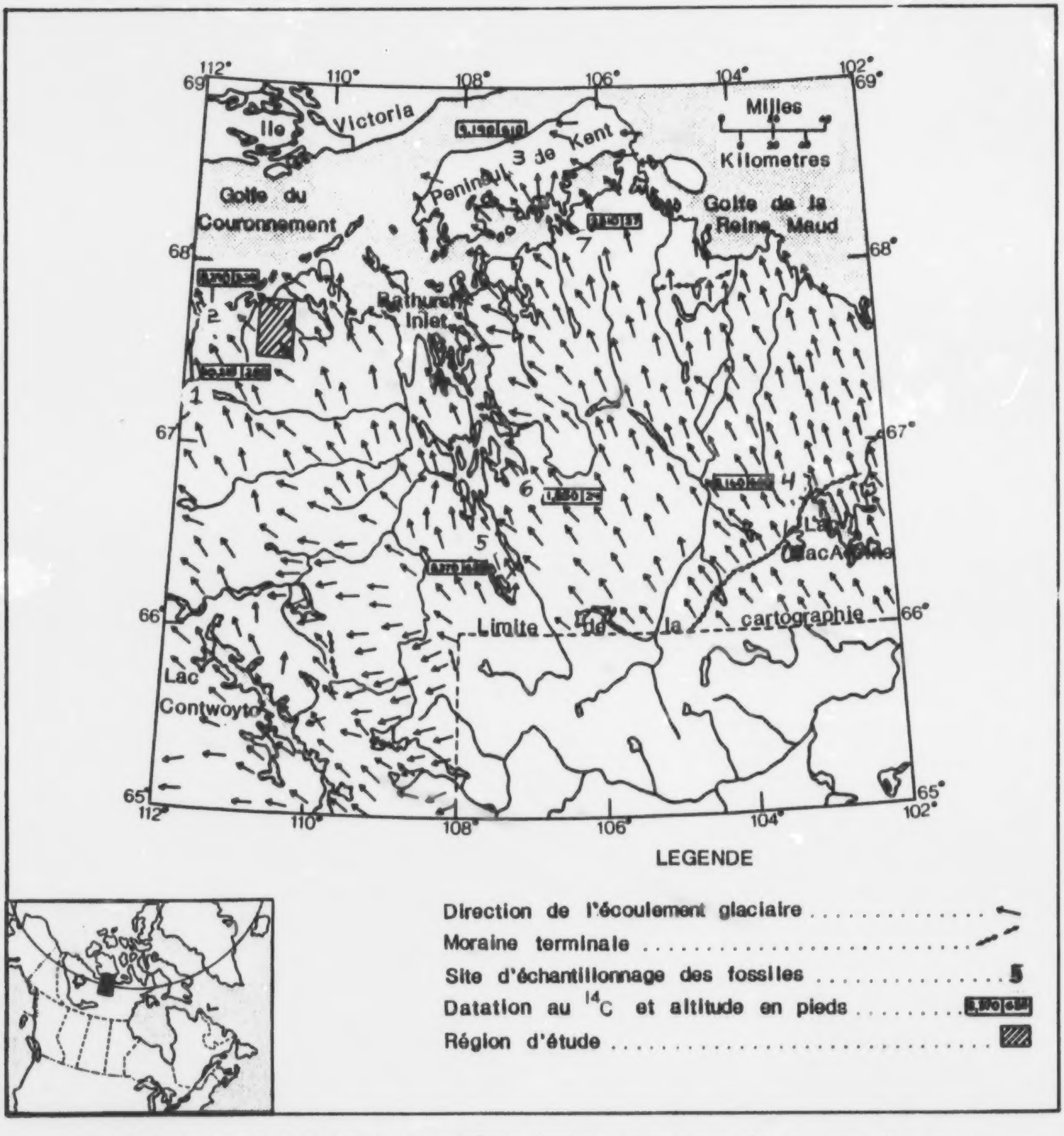

FIGURE 1: Carte de localisation de la présente étude et des travaux antérieurs (modifiée de Blake, 1963)

(c) Les sédiments fluvioglaciaires

D'importants dépôts fluvioglaciaires parsèment la région. Un complexe fluvioglaciaire de segments d'eskers et de terrasses de kame occupe en partie une importante vallée qui s'étend de la partie sud-central de la région jusqu'au lac Doc en passant par le lac Franklin (fig. 2). Ces dépôts de gravier et de sable avec des blocs et des cailloux atteignent 45 m d'épaisseur. Ce même matériel se retrouve à l'amont des sédiments de contact glaciaire. Plusiers kettles percent la surface des dépôts fluvioglaciaires.

A l'ouest du lac Doc, ce système d'eskers aboutit à un important delta atteignant au moins 97 m d'épaisseur. Un petit esker sépare ce delta d'un autre delta d'une élévation similaire situé plus au nord dans la même vallée (fig. 2).

Composés de galets, de cailloux, de gravier, de sable et de quelques blocs anguleux ces deltas atteignent 220 m a.n.m. Plusieurs chenaux, maintenant abandonnés, sillonnent leur surface. Ils occupent une large vallée structurale perpendiculaire à l'écoulement des glaces. Leurs versants très raides leur confèrent une apparence de mesa. Plusieurs grands kettles percent la surface amont de ces deltas qui définissent un ancien plan d'eau dont l'origine sera discutée plus loin.

(d) Les sédiments marins

Suite au retrait du front glaciaire, l'invasion marine atteint 200 m a.n.m. Ce niveau maximum est également marqué par la distribution spatiale de dépôts de silt, d'argil et de sable contenant des fossiles marins (fig. 2). D'après la carte topographique 76M, le lac Franklin se situe à 656' a.n.m. soit à 200 m a.n.m. Cependant aucune évidence ne laisse suggérer que la mer ait atteint ce lac. Toutefois une crête de matériel d'éboulis de 5 m au-dessus du niveau du lac bloque l'extrémité nord-est de ce lac (fig. 2). Cette crête est sensiblement remaniée du côté nord-est mais ne montre aucun remaniement du côté sud-ouest, c'est-à-dire du côté du lac Franklin. La mer ne submerga peut-être pas cette crête situéeà environ 205 m a.n.m., mais les vagues ont pu remanié le bas de la crête du côté nord-est. Le niveau marin maximum de 200 m a.n.m. concorde avec les résultats de Craig et Blake qui l'etablissent entre 650 et 700 pieds soit 186 et 213 m a.n.m.

Les sédiments marins comprennent des sédiments fins déposés en eau profonde et des sédiments de plages déposés dans un environnement littoral. Les sédiments fins sont composés de silt et d'argile laissant place ensuite à du sable fin. Ces sédiments atteignent 20 m d'épaisseur. La séquence de sédiments fins à grossiers marque une régression marine. Les sédiments de plage (fig. 2) sont composés de cailloux, de gravier, et de sable grossier à fin atteignant 4 m d'épaisseur. Ces plages soulevées sont particulièrement bien dévelopées dans la vallée de la rivière Kennarctic, près du niveau marin actuel. Les coquillages marins sont abondants dans la région couverte de sédiments marins, jusqu'à des altitudes de 195 m a.n.m. En surface c'est généralement au centre des ostioles qu'on les retrouve ce qui traduit un brassage cyrogénique dans les cellules. En coupe, ces fossiles sont concentrés surtout dans la zone de contact entre le silt argileux et le sable fin.

(e) Les alluvions

Suite à la régression marine, la rivière Kennarctic reprit son cours vers la mer ce qui a

TABLEAU 1

Liste des datations au ^{14}C

Site (figure 1)	Numéro de datation	Altitude approximative de l'échantillon (pieds a.n.m./m a.n.m.)	Matériel daté[1]	Age (années B.P.)
1	I(GSC)-17[2]	280/85	*Macoma calcarea* (Gmelin)	10,215 + 220
2	I(GSC)-13[3]	320/98	*Hiatella arctica* (L.) et *Mya truncata* L.	8,290 + 330
3	GSC-125	610/186	*Mya truncata* L.	9,190 + 210
4	GSC-110	600/183	*Hiatella arctica* L.	8,160 + 140
5	GSC-115	650-670/198-204	*Hiatella arctica* L., *Mya* sp., et *Macoma balthica* (L.)	8,370 + 100
6	GSC-137	24/7	*Mytilus edulis* L.	1,850 + 140
6	GSC-138	19/6	feuilles et branches de bouleau, aulne et saule	2,170 + 140

[1] Coquillages identifiés par F.J.E. Wagner de la Commission géologique du Canada, excepté pour I(GSC)-13 (voir W.H. Dall *dans* O'Neill, 1924, p. 31).

[2] Collectionné par Craig en 1959, publié par Craig (1960, p. 6) et Craig et Fyles (1960, p. 12).

[3] Collectionné par O'Neill (1924, p. 33) en 1915, publié par Craig (1960, p. 6) et Craig et Fyles (1960, p. 12).

Source : Blake, W., Jr (1963). Notes on Glacial Geology, Northeastern District of Mackenzie

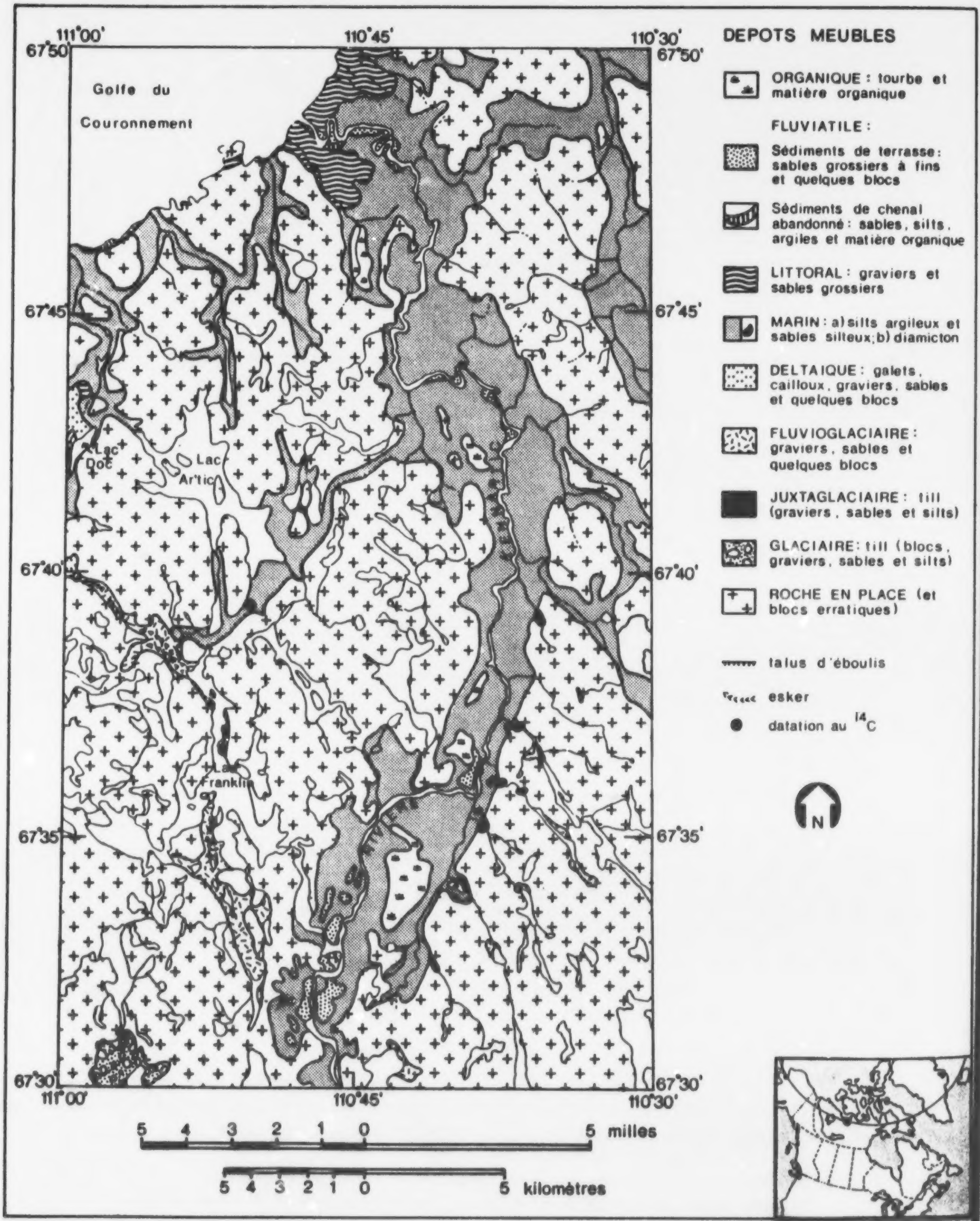
111°00'
110°45'
110°30'
67°50'
67°45'
67°40'
67°35'
67°30'
Golfe du Couronnement
Lac Doc
Lac Ar'tic
Lac Franklin
DEPOTS MEUBLES
ORGANIQUE : tourbe et matière organique
FLUVIATILE :
Sédiments de terrasse: sables grossiers à fins et quelques blocs
Sédiments de chenal abandonné : sables, silts, argiles et matière organique
LITTORAL : graviers et sables grossiers
MARIN : a) silts argileux et sables silteux; b) diamicton
DELTAIQUE : galets, cailloux, graviers, sables et quelques blocs
FLUVIOGLACIAIRE : graviers, sables et quelques blocs
JUXTAGLACIAIRE : till (graviers, sables et silts)
GLACIAIRE : till (blocs, graviers, sables et silts)
ROCHE EN PLACE (et blocs erratiques)
talus d'éboulis
esker
datation au 14C
N
5 4 3 2 1 0 5 milles
5 4 3 2 1 0 5 kilomètres

FIGURE 2: Lithologie des dépôts meubles

entrainé une importante sédimentation fluviale. Le rebondissement isostatique est responsable de l'incision de la rivière dans ses propres sédiments et dans les sédiments marins, exposant des coupes atteignant 24 m de hauteur. Des lambeaux de terrasse fluviatile marquent le niveau d'une ancienne plaine alluviale (fig. 2). Ces terrasses sont formées de cailloux, de galets, de gravier et de sable grossier à fin. Ces dépôts atteignent 15 m d'épaisseur.

Des chenaux abandonnés sont également exposés en coupe. Ils sont comblés de sable grossier à fin, de silt, d'argile, le tout parsemé de matériel organique. Ces dépôts atteignent 4 m d'épaisseur.

(f) Les dépôts gravitaires

Les processus les plus actifs présentement sont sûrement les porcessus de gravité. Ainsi des talus d'éboulis sont continuellement nourris par les blocs se dégageant des falaises. Le plus bel exemple se trouve le long des sills de diabase de Franklin (E.G.S. 1982-6). La solifluction a complètement remanié la surface des sédiments fins marins de la région. A certains endroits elle forme des lobes sur des pentes de moins de 2^{o}.

(g) Les sediments organiques

Les sédiments organiques sont fréquents dans la région où ils tapissent presque entièrement la surface des sédiments fins marins. La tourbe dépasse fréquement 1 m d'épaisseur. Des débris de buisson sont une partie importante de ces dépôts organiques.

INTERPRETATION

L'empreinte des processus liés au retrait des glaces du Wisconsinien est dominante dans les formes et les sédiments du Quaternaire de la région. Diverses étapes de déglaciation peuvent être définies d'après les évidences géomorphologique et sédimentologiques.

Etape 1

La Glace recouvrait la quasi totalité de la région étudiée. Une val;lée située immédiatement à l'ouest de la région, libérée de l'emprise des glaces, était occupée par les eaux marines. Le matériel transporté par les eaux de fonte en aboutissant dans ce bras de mer contruisit des deltas dont l'altitude atteint environ 220 m a.n.m. Ces deltas furent donc formés de matériel très grossier mis en place directement par les eaux de fonte dans un niveau marin plus élevé. La morphologie de ces deltas résulte d'une sédimentation au contact de la glace: "the steep sides of the raised deltas, which are mesalike, indicate that they were formed between ice walls... the absence of river channels upstream from the deltas, but instead a series of eskers (topographicallylower) leading up to the deltas, also indicates the presence of ice" (Blake, 1963, p.7-8). La présence des kettles sur la surface de ces deltas est un autre indicateur de la présence de glace enfouie par les sédiments et dont la fonte subséquente provoquera l'affaissement du matériel et l'affaissement du matériel et l'apparition des kettles.

Etape 2

Le retrait du glacier vers l'est retira la source des sédiments formant les deltas. L'immersion marine contemporaine du retrait des glaces atteint un niveau maximum marqué par des plages soulevées qui ont remanié les versants des deltas jusqu'à 200 m a.n.m. La sédimentation dans cette mer postglaciaire recouvre les basses terres d'une couche de sédiments fins. Ces sédiments contiennent des fossiles que l'on retrouve un peu partout. Le résultat d'une datation préliminaire au ^{14}C de coquillage marins, pris à l'interface de silt argilieux et de sable dans une copur située environ à 195 m a.n.m. (fig. 2), indique que la côte du golfe du Couronnement était libre de glace il y a 9,500 ans.

Le retrait glaciaire libéra également les eskers de leurs tunnels de glace. Des terrasses de kame furent ainsi formées à l'air libre. Aucune évidence permet de retracer le front glaciaire avant que celui-ci ne se trouve à l'est de la vallée de la rivière Kennarctic.

Etape 3

La position du front glaciaire à l'est de la rivière Kennarctic peut être déterminée par la présence des dépôts de contact glaciaire à l'embouchure de différents tributaires. Bein qu'il ne soit pas possible de fixer avec précision le tracé de ce front, la présence du diamicton et des sédiments de contact glaciaire indique la présence de glace à proximité. It est donc raisonable de supposer qu'à un moment donné le front de la glace en retrait se trouvait juste à l'est de la vallée de la rivière Kennarctic. Il est possible que ce front fut en partie en contact avec les eaux de la mer. Ceci expliquerait la pente raide des sédiments de contact glaciaire vers la vallée de la rivière Kennarctic ainsi que la présence de till dans une matirce de silt et d'argile au vas des dépôts de contact glaciaires. Cependant, en l'absence de coquillages marins dans le diamicton ou dans les sédiments de contact glaciaire cette explication ne peut être plus qu'un hypothèse.

Etape 4

A ce stage-ci la région est dégagée de glace, la mer a envahi la région jusqu'à la cote actuelle de 200 m a.n.m. et le rebondissement isostatique se fait sentir. Le rebondissement entraine un retrait progressif de la mer jusqu'à son niveau actuel, laissant une série de plages soulevées.

La rivière Kennarctic entaille les sédiments meubles qui deviendront des terrasses et elle construit une plaine alluviale parcourue par une rivière à méandre. La végétation envahit la région et comble les dépressions et les zones mal drainées d'un couvert organique qui peut dépasser 1 m d'epaisseur. La solifluction joue ensuite un rôle important dans le remaniement des dépôts de surface.

CONCLUSION

Les travaux de terrain ont permis de retracer l'évolution de cette région et de mieux comprendre les étapes de déglaciation de ce secteur du District du MacKenzie. Les datations radiométriques indiquent que le golfe du Couronnement est libre de glace depuis au moins 10,000 ans. L'importance de l'incursion marine postglaciaire, 200 m a.n.m., souligne l'importance de la masse de glace responsable de la dépression glacioisostatique de cette partie de la croûte terrestre. En comparant ces résultats à ceux de St-Onge et Bruneau (1982) le long de la rivière Coppermine on peut conclure à un rebondissement isostatique plus important d'environ 30 m pour la partie est par rapport à la partie ouest du golfe du Couronnement. Les résultats retirés de cette étude locale envers une meilleure connaissance des événements du Quaternaire dans l'Arctique canadien.

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MARTIN FROBISHER'S "GOLD MINES" ON KODLUNARN ISLAND AND ADJACENT BAFFIN ISLAND, FROBISHER BAY, NWT.

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ABSTRACT

Rocks of Kodlunarn Island are northwesterly trending biotitic quartzo-feldspathic gneiss and hornblende (biotite) gneiss with concordant lenses or layers of hornblende-biotite-andesine rock. The sequence dips to the southwest at moderate to high angles and is believed to be early Proterozoic.

Rocks piled near the two Frobisher trenches include hornblende-bronzite and spinel-hornblende rocks, which may have been transported from elsewhere during the old mining operations, as well as hornblende-biotite-andesine rock. These black rocks were probably all mined for gold by the Frobisher 2nd and 3rd expeditions of 1577 and 1578. An opening on the sea cliff of Baffin Island, opposite Kodlunarn, probably of natural origin, exposes a hornblende-augite-andesine rock.

"Gold" washed during the Frobisher expeditions may have been pyrite, but "gold" produced on roasting, appears to have been oxidized biotite. This oxidation begins well below red heat. No support could be found for the high gold assays of the Cathay Company. Average gold content in the various "black ores" were as follows:

hornblende-biotite-andesine rock -------------- 6 ppb
hornblende-bronzite-labradorite rock ---------- 5 ppb
spinel-hornblende rock ------------------------ 3 ppb
hornblende-augite-andesine rock --------------- 2 ppb

Platinum from ultrabasic rock could have been confused with gold in the old assays, but this theory could not be substantiated in the present study, where assays of up to 5 ppb Pt, or approximately 1/10 the crustal average for the element, were obtained. Ni, Cr and lithophile element abundances support a crustal parent, rather than direct mantle derivation, of the Frobisher "black ores".

INTRODUCTION

a) General

The Frobisher voyages of 1577 and 1578 were organized by the Cathay Company for the express purpose of finding and mining gold ore. Since publication of the Baffin expedition of Charles Francis Hall (Hall 1864), the location of Kodlunarn or Countess of Warwick Island, the headquarters of Frobisher's 3rd (1578) voyage, and focal point of the largest arctic voyage of all time, has been know to the world. Through Hall we also know the location of the Countess of Warwick Mine on Kodlunarn Island. However, the exact locations of the other mines are not known.

Of the "ore" we know little. Pieces of the original "black stone", once as large as "a half-penny loaf" have now disappeared altogether. Specimens collected at random from the repository of shipments in England and from loose rock on Kodlunarn Island were termed, respectively, "hornblende pyroxenite" and "amphibolite" (Roy 1937, p. 34) and from a locale about 200 yards from Kodlunarn as (hornblende) "pyroxenite" (Roy 1937, p. 37). However, it is uncertain whether these specimens are representative of Kodlunarn or of the other mines. although Blackadar (1967a) notes that, in the northern trench of Kodlunarn, biotite gneiss contains lenses and bands of amphibolite.

The "gold" itself is even less well defined. It has long been accepted that gold was virtually absent in Frobisher's ore. The "gold" has been termed pyrite, biotite and both biotite and pyrite together. Even the word "marquesset", which appears and reappears in contemporary descriptions, is nebulous and is defined as "a stone participating in the nature of some metal, yet in so small quantity, that the metal cannot be melted from it" (O.E.D., definition of 1616).

Many assays done in England and reported in Stefansson (1938, II, pp. 79-151) indicated high-grade concentrations of gold (greater than 60 g/t). The exact methods of the assays were not revealed but it appears from information in the British State Papers and by reference to accounts of the standard technology of the day (eg. Sisco and Smith 1951, pp. 112-115 and 124-128), that the method used in England involved lead fusion, cupellation, and acid parting, much the same as in modern fire assaying.

Since the return of Frobisher's 3rd voyage, these high assays have generally been regarded as false. Considering the well-developed assay technology in Elizabethan times and the apparent lack of ulterior motive of the assayers for falsifying data, these suspect high assays are indeed puzzling.

Assays ("proofes") made in the field may have been performed in a similar manner. Furnaces were set up on Kodlunarn and Newland Islands but details of their operations, the assay results and the provenance of the samples are not known. The "Booke of Register", reportedly listing these details, has long since disappeared.

In an attempt to solve some of these problems and provide further details on the operation of Canada's first "gold mines", the authors visited Kodlunarn Island and Fenton's Fortune (of Kenyon 1975, pp. 144-145) in August 1983, collected specimens from both localities and made a detailed geological survey of Kodlunarn Island. Specimens returned to Ottawa were studied petrographically, analytically (XRF, DCP and NAA) and mineralogically (electron microprobe). The authors would like to thank R. Hartree and J. Loop of the University of Ottawa for chemical analyses and P. Jones of Carleton University for microprobe work. The study was made possible by a Deparment of Indian and Northern Affairs contract in favour of one of us (D.D.H.).

b) Geographic information

Kodlunarn Island is on the west side of Countess of Warwick Sound, some 188 km southeast of the community of Frobisher Bay (Fig. 1). Its latitude-longitude is 62°48'N - 65°26'W, and its grid location, on the NTS 1:250,000 "Loks Land" sheet, is 20VLE7668. It can be reached by helicopter from Frobisher Bay or by boat, following a circuitous route around points and islands that normally takes two full days to travel.

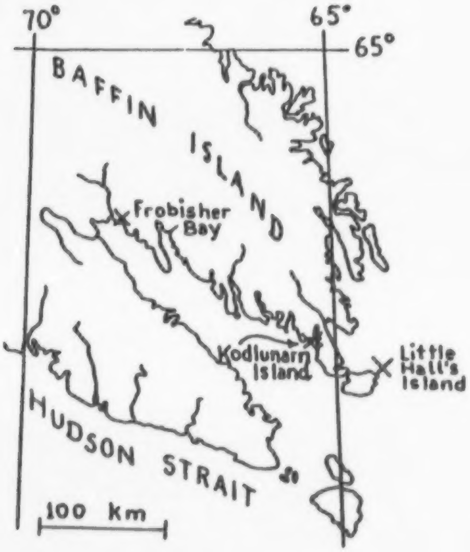

FIGURE 1: Locality plan

The islet rises abruptly 6 to 7 meters as a sea cliff from a gently sloping tidal flat; the summit is about 17 meters above high tide. This tide is normally about 10 meters. The island measures about 400 meters long and 350 meters across at its widest and totals 8 hectares in area.

Kodlunarn Island and adjacent Baffin Island are well within permafrost limits. Even in August, ground is frozen within 0.3 m to 1 m of the surface, which is covered with loose shingle and boulders and interrupted by the occasional protrusion of solid rock. The only continuous outcrop is found along the sea cliffs. These hostile soil and climatic conditions permit scant flora only, including rare ground-hugging Salix arctica (a willow), Betula glandulosa (a birch) and thin tufts of grass and sedges.

The north side of the island is cut by the well-documented "Ship's Trench" while the central portion is pierced by the "Reservoir Trench" (see Fig. 2). Of the numerous publications dealing with geographical features and historical incidents related to this island, probably the most accessible, and certainly the most complete, are the two volumes edited by Vilhjalmur Stefansson (1938). Further information is given by Kenyon (1975; 1981).

Fenton's Fortune (Kenyon 1975, pp. 144-145) is an opening in the sea cliff of Baffin Island, near tidewater, approximately 1.5 km NW of Kodlunarn. Its latitude-longitude is 62°50' N, 65°27' W and its grid location is 20VLE7569. It has been reported as a possible mine site of Frobisher (Kenyon 1975).

GEOLOGY

Little has been written on the geology of this area. A summary, with accompanying geological map on 1:500,000 scale, was published by Blackadar (1967b). All rocks were described as early Proterozoic (Aphebian) metamorphics. More particularly, the rocks of Kodlunarn Island were placed in unit 3, a charnockitic quartz-feldspar gneiss. No other geological report exists. The following description is based on data gathered during the present investigation.

Bedrock is divided into four units, and subdivided into additional subunits where necessary. The sequence is summarized in the table of formations (Table 1).

TABLE 1: TABLE OF FORMATIONS, KODLUNARN ISLAND

Aphebian or later	4. Dykes and veins - a. granite pegmatite b. quartz veins c. hyaline dykes
	INTRUSIVE CONTACT
APHEBIAN	3. Mafic rocks a. hornblende-biotite-andesine rock b. hornblende-bronzite-labradorite rock c. spinel-hornblende rock d. hornblende-augite-andesine rock e. actinolite-diopside-phlogopite rock
	2. Hornblende-rich gneiss a. hornblende gneiss b. hornblende-biotite gneiss
	1. Quartzo-feldspathic gneiss

(Units 1 to 3 are not necessarily in chronological order).

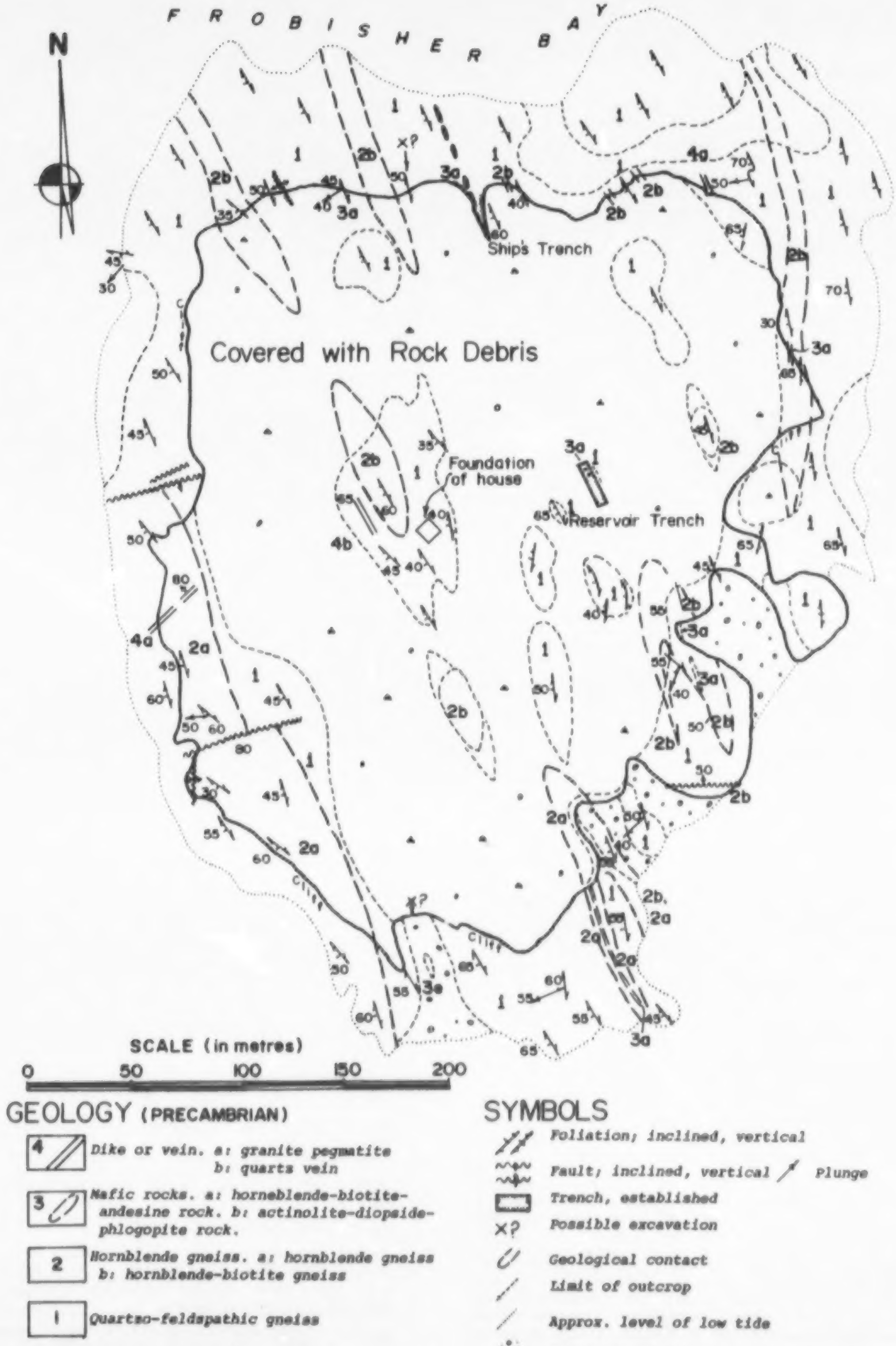
F R O B I S H E R B A Y
N
Covered with Rock Debris
Ships Trench
Foundation of house
Reservoir Trench
Cliff
SCALE (in metres)
0
50
100
150
200
GEOLOGY (PRECAMBRIAN)
4 Dike or vein. a: granite pegmatite b: quartz vein
3 Mafic rocks. a: horneblende-biotite-andesine rock. b: actinolite-diopside-phlogopite rock.
2 Hornblende gneiss. a: hornblende gneiss b: hornblende-biotite gneiss
1 Quartzo-feldspathic gneiss
SYMBOLS
Foliation; inclined, vertical
Fault; inclined, vertical
Plunge
Trench, established
×? Possible excavation
Geological contact
Limit of outcrop
Approx. level of low tide
Cobble-paved cove

FIGURE 2: Geology of Kodlunarn Island

Quartzo-feldspathic gneiss (1)

The principal rock type at Kodlunarn Island and adjacent Baffin Island is a fine-grained, grey leucocratic gneiss characterized by oligoclase, quartz, minor brown biotite and varying amounts of microcline. Rarely is hornblende the main dark mineral. This rock apparently corresponds to unit 4 - grey granitic gneiss of Blackadar (1967b).

Hornblende-rich gneiss (2)

Hornblende-rich gneiss occurs as lenses and interlayers in quartzo-feldspathic gneiss. The rock is dark green, fine granular, and distinctly layered with alternate feldspathic and mafic strata. Mineral foliation is poorly defined. Recognized variants are:

2a. hornblende gneiss as at the southwest of Kodlunarn Island. Biotite is not abundant (less than 5%).
2b. hornblende-biotite gneiss. This rock is distinguished by essential biotite (5-20%). A typical exposure is on the east side of Kodlunarn Island.
2c. hornblende-augite-biotite gneiss. This rock differs from other variants in being coarse grained and porphyroblastic (hornblende metacrysts). It also contains considerable augite, andesine and microcline. It is seen at Fenton's Fortune.

Mafic rocks (3)

These include Frobisher's "black ores" and are therefore of special significance. They will be considered in the next section.

Units 1 to 3 have a planar fabric defining a monocline, with rocks striking NW and dipping SW at moderate to high angles (50-70 degrees common), although shallow, steep and even reversed dips were observed locally. Minor folds, generally tight to isoclinal, are common, with plunges shallow to moderate (30-50 degrees) W and NW. Steeply dipping faults most commonly trend approximately EW and, more rarely, NNW. Shallow-dipping, open shear zones, possibly recent adjustments to uplift, were observed in the north and northwest parts of Kodlunarn Island. Mylonite was collected from loose blocks but was not seen in place. These rocks have been affected by the Hudsonian orogeny (ca. 1800 m.a.).

Dykes and veins (4)

Four minor, discordant rocks were observed.

4a. Granite pegmatite dykes. These are of the Quartz-perthite-biotite type. One in the northeast part of Kodlunarn Island is distinctly zoned with a well-developed quartz core.

4b. Quartz veins. One of these, seemingly completely lacking other minerals, was observed a few meters northwest of the remains of Frobisher's house.

4c. Hyaline dykes. Towards the northeast of Kodlunarn Island, several anastomosing black dyklets (max. width 1 cm) cut hornblende-rich gneiss. One of these is composed of yellowish brown glass containing a few scattered crystals of plagioclase. This rock may represent a chilled equivalent of Blackadar's unit 16 (diabase), the Baffin extension of the 675 m.y. old Franklin swarm (Fahrig et. al. 1971), although these dykes are somewhat old for the persistence of glass.

The last known events were Pleistocene glaciations and Pleistocene-Recent uplift. The uplift is manifest by rudely defined raised beaches extending to the very top of the island, 22 meters above mean sea level.

MAFIC ROCKS (UNIT 3)

From various accounts, this rock, "a blacke stone, much lyke to a seacole in colour", seems to represent the type sought, and almost exclusively mined, in the last two Frobisher expeditions. At Kodlunarn, the rock is present as two principal layers or lenses trending NNW and dipping steeply W, and is concordant with the local gneisses (see Fig. 2). One of these, traced across the island, is included in the two Frobisher trenches. Specimens were first collected from a shallow hole excavated in the floor of the Resevoir Trench in 1975, then in situ in the Ship's Trench in 1983, and finally from remnants of stockpiles near the trenches themselves. As distinct from nearby fragments, rocks in the stockpiles were very dark and partly covered with blackened lichen, believed to indicate great age (cf. Roy 1937, pp. 32-33). Some specimens on the stockpiles closely resembled the rocks in situ, but those selected for study were macroscopically different. Modal analyses of the 'black rocks' listed below are given in Table 2.

Three variants have been noted (Table 1).

3a. Hornblende-biotite-andesine rock. This is the only subunit definitely observed in situ on Kodlunarn Island. Common hornblende and plagioclase (An 35) are the dominant minerals, green biotite is somewhat less abundant. Opaque minerals constitute about 1% of the rock's volume and are mainly pyrrhotite in small grains, with lesser chalcopyrite and pyrite. Some magnetite replaces biotite. Individual layers or lenses attain widths of up to 35 cm, and the aggregate width of several layers does not surpass 0.7 m. Biotite is most abundant towards the edge of these lenses and the rock is separated from the enclosing gneiss by a selvage of fine-grained biotite. Hornblende is roughly oriented with its prismatic axis in the mica foliation plane and parallel to the foliation of the surrounding gneiss. The long dimension of grains (3-6 mm) is roughly twice the long dimension of mica crystals.

3b. Hornblende-bronzite-labradorite rock. Loose specimens were collected from both the Ship's Trench and Reservoir Trench. Hornblende is the main constituent, followed by labradorite and green biotite. Labradorite is strongly zoned from An 60 in the cores to An 50 on the rims of grains. A small amount of bronzite-hypersthene (Fs 15) is typical. Tiny, interstitial pyrite grains, some rimmed with hematite, are very rare.

3c. Spinel-hornblende rock. This rock is coarser grained than that of subunits 3a and 3b and is very dark green (rather than black). Specimens examined were of two types:

Type 1 - Spinel-hornblende-olivine rock (specimen K5C). This rock was collected loose from

TABLE 2: MODAL ANALYSES OF BLACK ROCK, COUNTESS OF WARWICK SOUND

No.	Location	Subunit	Plagioclase compn	Plagioclase	Quartz	Actinolite or hbde	Diopside or augite	Hypersthene or bronzite	Olivine	Spinel	Mg-mica	Chlorite	Apatite	Black Fe oxide	Pyrite	Others & Remarks
K5A	"in situ", bottom S.T.	3a	An35	30		50					20	+		5		massive, very coarse grained
K5B	"in situ", botton S.T.	3a	An34	30		50		10			10			++	++	massive, very coarse grained
K5C	loose, bottom S.T.	3c				30			35	30				5		massive, very coarse grained
K8A	loose, top S.T.	3b	An60	15		60		+			20		5	+		coarse grained
K8B	loose, top S.T.	3c		5	5	75				15				5		coarse grained Quartz with carb. as veinlet
K9B	"in situ"(?) bottom R.T.	3b	An60	15		65		15			5			+	+	coarse grained, rare carbonate
K9C	loose, bottom R.T.	3c	An38	5		75		+		20	+			++	+	coarse grained; carb, corundum rims spinel, saponite
K9D	loose, top R.T.	3c		5		80				20				++	+	coarse grained, rare carbonated
K9E	loose, top R.T.	3b?		10		80		10							+	coarse grained
K10A	"in situ" F.F.	3d	An44	40		30	20							10	1	
K10C	"in situ" F.F.	3d	An39	30		30	30	+			5			10		weakly foliated porphyroblastic (hbde megacrysts)

Abbreviations: F.F. - Fenton's Fortune, R.T.-Reservior Trench, S.T.-Ship's Trench + *present*

the north end of the Ship's Trench. Spinel (pleonaste) occurs in poorly defined clusters. The specimen contains about 5% opaques, mainly magnetite and magnetite intergrowths. Plagioclase and biotite are absent.

Type 2- Spinel-hornblende-biotite-andesine rock (specimens K8B, K9C, K9D). These specimens were collected loose from both the top of the Ship's Trench and Reservoir Trench. Spinel (hercynite) occurs in rounded octahedra. The central part of the largest crystals has exsolved magnetite. Small amounts of andesine and green biotite are characteristic. Magnetite and magnetite-ilmenite intergrowths make up 1-5% of the rock. Pyrite, chalcopyrite and pyrrhotite occur in very rare, tiny grains.

3d Hornblende-augite-plagioclase rock. This rock occurs in situ at "Fenton's Fortune". It is interlayered with hornblende-augite-biotite gneiss from which it differs by containing a greater proportion of mafic minerals. Planar fabric is distinct and layers bend around elongated (up to 3 cm) hornblende metacrysts. Contact with the surrounding gneiss is gradational. Black biotite is minor. Opaques totalling 5-10% volume are mainly coarse-grained magnetite and magnetite-ilmenite intergrowths. Pyrite, chalcopyrite and very rare pyrrhotite are distributed throughout as tiny grains.

3e Actinolite-diopside-phlogopite rock. This is found at the southern end of Kodlunarn Island and may be equivalent to unit 3d, although plagioclase is absent.

CHEMICAL COMPOSITION

X-ray fluorescent analyses (data summarized in Table 3) show that all rocks are rich in aluminum (13 to 21% Al_2O_3) and the "black ores" specially rich in magnesium (10 to 18% MgO) and iron (10 to 15% FeO), although subunits 2c and 3d from Fenton's Fortune are notably poorer in magnesium (5 to 6% MgO).

An abundance of lithophile elements (eg. 2 to 3% Na_2O, 1 to 2% K_2O, 9 to 12% CaO) and a low content of mantle-type elements (100 to 300 ppm Cr,

TABLE 3: X-RAY FLUORESCENT ANALYSES OF SPECIMENS FROM COUNTESS OF WARWICK (KODLUNARN ISLAND) AND FENTON'S FORTUNE (BAFFIN ISLAND) MINES.

	COUNTESS OF WARWICK MINE					FENTON'S FORTUNE MINE	
Unit or subunit	1 (wall rock)	3a	3b	3c	3c(K5A)	2c (wall rock)	3d
Number of specimens	2	2	2	3	1	1	2
SiO_2%	68.3 ±2.3	46.1±0.6	44.8+1.0	39.9±0.4	31.0	53.2	46.9±0.1
Al_2O_3%	15.4±0.3	15.5±0.2	14.9±0.5	15.4±0.8	21.0	14.2	13.6±0.5
FeO_T%	3.3±1.1	12.5±0.3	11.3±0.3	10.9±0.4	14.7	10.8	13.8±0.3
MgO%	1.4±0.5	10.3±0.2	13.3±0.8	14.8±0.5	17.8	5.1	6.4±0.06
CaO%	4.0±0.6	9.3±0.1	9.9±0.9	11.4±0.5	11.2	8.6	11.6±0.3
Na_2O%	4.2±0.2	2.5±0.1	1.8±0.05	1.9±0.2	0.5	3.5	2.9±0.1
K_2O%	1.1±0.1	1.7±0.1	1.6±1.2	0.3±0	0.1	1.3	0.8±0.1
Ni ppm	15±5	220±10	380±10	400±30	600	90	90±10
Cr ppm	20±0	200±10	330±160	180±20	290	130	140±5

Analyst: R. Hartree, University of Ottawa.

100 to 400 ppm Ni) suggests that the "black ores" were crustally derived. However, specimen K5C is enigmatic, being quite different from the other rocks; it is comparatively poor in alkalis and silica but richer in nickel. These and other differences suggest that this rock, one of the specimens collected loose from the Ship's Trench area, may have been derived from a locality separate from other rocks of type 3c and perhaps from all the other "black ores".

ORE MINERALOGY

Eight polished thin sections were examined with the ore microscope. From these, six polished thin sections representing the four "black rock" types (Units 3a to 3d) were selected for microprobe work at Carleton by Peter Jones, analyst. A brief summary of oxide and sulphide mineralogy follows.

The main black oxide is magnetite with subordinate ilmenite, the latter either as exsolved lamellae in magnetite or as isolated grains. Ilmenite from specimen K5C (Kodlunarn Island) is somewhat magnesian and manganiferous (3 to 4% each of MgO and MnO). Those from other specimens have less manganese and magnesium. Ilmenite from K10C (Fenton's Fortune) is comparatively magnesium-poor (0.35% MgO). A small amount of niobium (up to 0.2% Nb_2O_5) appears to be present in all ilmenites.

The green oxide is pleonaste (65% Mg-spinel, 35% Fe-spinel) in specimen K5C but hercynite (45% Mg-spinel, 55% Fe-spinel) in specimens K8B and K9D.

Sulphides are mainly present as small rounded grains. The main sulphide would appear to be pyrrhotite, with lesser amounts of chalcopyrite and pyrite. The pyrite is partly oxidized to hematite. A very small amount of millerite is present in specimen K5C closely associated with calcite.

Needless to say, with the very minor amount of precious metals determined by chemical analysis (Table 5,) no native gold, silver or platinum was detected in any specimen.

THE FROBISHER MINERALS

What mineral first attracted the attention of the "venturers". According to George Best (in Stefansson 1938, I, p. 51), back in England one of the sailors' wives cast into the fire a piece of coal-black rock of the first voyage, removed it, quenched it in vinegar, and found that it "glistened with a bright Marquessete of golde". Another report (an unpublished manuscript) has Robert Garrand, the discoverer of the black rock, tossing a piece into the ship's fire "to prove it would burne". The last report seems the most likely but, common to both accounts, the rock was subjected to ignition.

In order to investigate the appearance of the black rock after heating, 10 specimens were roasted at various temperatures in a muffle furnace. As can be seen (Table 4) a golden mica is readily produced. This yellowing was first observed in one specimen at 400°C, and at 800°C is more or less complete for all specimens containing phlogopite-biotite. 800°C also marks the temperature of greatest contrast of golden yellow against a pitch-black background. By 1000°C magnetite has partly oxidized to hematite, and hornblende has taken on a slightly brownish cast. Pyrite has long since oxidized to hematite at these high temperatures. Exceptional is specimen K10C from Fenton's Fortune where the mica (here an iron-rich biotite) began to oxidize at 1000°C only, but even at this extreme temperature many biotite flakes seem to have emerged from the furnace unscathed.

We may conclude that Best's "marquesset of golde" was phlogpite-biotite, oxidized after heating to moderate or high temperatures, and whose true

TABLE 4: HEATING EXPERIMENTS ON "BLACK ORES" FROM KODLUNARN

No.	Microscopic appearance of unheated Mg-mica	400°C	600°C	800°C	1000°C
K5A	Green biotite (A_{40}) 20%	unchanged	unchanged	unchanged	Hbde with brownish cast
K5B	Green biotite (A_{35}) 10%	Mica somewhat golden	Mica distinctly golden	Mica strongly golden	Hbde with brownish cast Mica strongly golden
K5C	Not observed	unchanged	unchanged	unchanged	Hbde with brownish cast
K8A	Green phlogopite (A_{30}) 20%	unchanged	Mica distinctly golden	Mica strongly golden	Hbde with brownish cast Mica strongly golden
K8B	Colourless phlogpite (A_{15}) <1%	unchanged	unchanged	Mica (rare) strongly golden	Hbde with brownish cast Mica (rare) strongly golden
K9C	Green biotite (A_{40}) <1%	unchanged	Hypersthene dist. golden Mica distinctly golden	Hypersthene dist. golden Mica (rare) strongly golden	Hbde with brownish cast Hypersthene dist. golden Mica strongly golden
K9D	Not observed	unchanged	unchanged	Mica strongly golden	Hbde with brownish cast Mica distinctly golden
K9E	Not observed	unchanged	unchanged	unchanged	Hbde with brownish cast
K10A	Not observed	unchanged	unchanged	unchanged	Hbde with brownish cast Some mica partly golden
K10C	Brown biotite (A_{72}) 5%	unchanged	unchanged	unchanged	Hbde with brownish cast Some mica partly golden Some mica unchanged

In parentheses, compositions, mol% annite (phlogopite-annite series) from chart of Winchell & Winchell (1951 p. 347) (measured γ values: K5A=1.632, K5B=1.624, K8A=1.616, K8B=1.596, K9C=1.632, K10c=1.668); Second figure represents volume % of thin section.

identity as a mica was missed because of its minute size (average grain length 1.5 mm). However, it is possible that the "marquessete" was bronzite-hypersthene, also yellowed after roasting.

We have few clues to the identity of so-called gold in the unheated rock. Best notes that the ore of Kodlunarn Island "in the washing held golde plainly to be seene" (Stefansson 1938, p. 64). Roy and Tilley believe the "gold" to have been biotite (Roy 1937), but the mica encountered in this investigation was greenish black and can hardly be considered a candidate. On the other hand, pyrite was noted in 5 of the 8 specimens of "black ore" collected at Kodlunarn. At the bottom of the Ship's Trench a network of thin pyrite veinlets was observed in situ. Pyrite would, therefore, seem a more likely mineral. However, the weathered brassy to bronzy biotite, described by Roy and Tilley (Roy 1937), while not observed in the present investigation, presents a possible alternative.

PRECIOUS METAL ANALYSES

Thirteen specimens were tested for Ag, Au, PGE by direct current plasma (DCP) at University of Ottawa.

Silver -

A crushed and ground, 100 mg-sample was dissolved in hot HNO_3 and the solution was analysed by DCP.

Gold and Platinum -

10-gm samples were made from crushed and ground specimens. A measured amount of silver, in solution, was added to the ore-flux mixture and a silver bead containing all the gold and platinum in alloy was obtained by standard Pb-fusion fire-assay methods. This work was performed at the Bondar-Clegg laboratories in Ottawa. The bead was then dissolved in aqua regia and the DCP readings were taken at the University of Ottawa. Samples were run in duplicate (with good precision) and checked against standards and blanks. John Loop was in charge of all analyses. Data are summarized in Table 5.

Eight samples were then analyzed by neutron activation analysis (NAA) by Nuclear Activation Services Ltd. of Hamilton, Ontario, under the direction of Dr. Eric Hoffman. Nickel-sulphide extractions were made from 50-g samples and NAA determinations were made for Au and PGE. Pt, Au and Ir data are listed in Table 5. With the exception of sample K5B (which gave 8 ppb), all other elements were below detectability.

TABLE 5: ANALYSES OF PRECIOUS METALS IN SAMPLES OF 'BLACK ORE' FROM KODLUNARN

No.	Location (1)	Unit or Subunit (2)	D C P (3) Ag	D C P (3) Au	D C P (3) Pt	N A A (4) Pt	N A A (4) Au	N A A (4) Ir
K5A	in situ, bottom S.T.	3a	50	8	50	--	--	--
K5B	in situ, bottom S.T.	3a	50	6	50	5	5	0.2
K5C	loose, bottom S.T.	3c	50	2	50	5	5	0.2
K7	footwall, bottom S.T.	1	50	2	50	--	--	--
K8A	loose, top S.T.	3b	75	2	50	5	1	0.1
K8B	loose, top S.T.	3c	50	7	50	5	3	0.3
K9A	footwall, R.T.	1	50	2	50	--	--	--
K9C	loose, bottom R.T.	3c	50	8	50	5	3	0.3
K9D	loose, top R.T.	3c	50	9	50	5	3	0.2
K9E	loose, top R.T.	3b(?)	50	11	50	--	--	--
K10A	in situ, F.F.	3d	50	--	--	5	2	0.2
K10B	wallrock, F.F.	2c	50	4	50	--	--	--
K10C	in situ, F.F.	3d	50	--	--	5	2	0.1
	Crustal abundance (5)		75	3.5	46	--	--	--
	Ultrabasic rocks (6)		80	11.4	65	--	--	--

(1) Abbreviations as in Table 2

(2) Units, subunits as in Table 3

(3) J. Loop, Univ. Ottawa, analyst

(4) E. Hoffman, NAS, Hamilton, analyst

(5) Li and Yio quoted by Boyle (1973, p. 16)

(6) Boyle (1979, p. 38; 1982)

Gold contents approximate the crustal average and reached Boyle's ultrabasic rock average in one specimen only (K9E, rock subunit 3b). A "best value" for each "black ore" type is as follows:

hornblende-biotite-andesine rock (3a)	6 ppb
hornblende-bronzite-labradorite rock (3b)	5 ppb
spinel-hornblende rock (3c)	3 ppb
hornblende-augite-andesine rock (3d)	2 ppb

Silver approached crustal abundance in one specimen only (K8A). This rock, subunit 3b, strangely was one of the few specimens showing no sulphide at all, microscopically or macroscopically. All other assays were below the detection limit (50 ppb).

Platinum is also low and gives no support for a mantle-derived rock. NAA data suggest the "black ores" contain approximately 1/10 crustal abundance Pt.

CONCLUSIONS

Rock was quarried from two sites on Kodlunarn Island, the Ship's Trench and the Reservoir Trench, along a band containing micaceous amphibolite (subunit 3a). High-grade material was stockpiled nearby, possibly together with rock brought from other locales. The Ship's Trench was at tidewater and may have been used as a drydock in the third voyage, after the finish of mining operations at this site. Likewise, the Reservoir Trench may also have had an auxiliary use, here as a source of fresh water in the later stages of the third voyage. However, Best (Stefansson, I, p. 104) infers that a closely guarded "spring" supplied at least some of the drinking water requirement.

Of the three types of "black rock" found loose on Kodlunarn, one only (Subunit 3a) can be correlated with rock in situ. Subunit 3b perhaps belongs here also, but no evidence whatsoever could be found linking subunit 3c with any rock in place. It is thought that 3c and probably 3b were derived from one or more locales bordering the Countess of Warwick Sound.

It appears that Walter Kenyon's "Fenton's Fortune Mine" (Kenyon 1975, pp. 144-145) is located inaccurately. Contemporary information pinpoints the mine on the east side of the Countess of Warwick Sound. It is even doubtful whether this was a mine at all. There are no obvious chisel marks or man-broken rocks. The opening follows a well-developed joint pattern. It is very close to (within a meter of) tidewater and would appear to have been well within the tidal range since Frobisher's day. It probably represents a sea cave.

The golden mineral originally washed from crushed rock is thought to have been pyrite or chalcopyrite which occur irregularly in small amounts through the "black ore". On the other hand, "gold" produced in the fire probably represented a green mica that oxidized to golden yellow long before red heat. In the latter case, it is assumed that the rock from Little Hall's Island (the original discovery, not seen) reacted on firing similarly to the Kodlunarn rocks. Mica in subunit 3d from Kenyon's "Fenton's Fortune" was not oxidized at these temperatures.

Gold and silver contents in our specimens were very low, mostly below crustal abundance. This is not at all surprising, considering the specimens represent rocks of basic to ultrabasic compositions - probably crustally derived as metamorphic rock.

Platinum affords a special interest. The metal was unknown in Frobisher's day (it was first characterized by Sir William Watson, an English physicist, in 1750) and the early assayers could have confused the high Pt in ultrabasics with Au. During fire assaying, Pt would, like Au, be partitioned into the lead fraction and, ultimately, into the bullion bead. This could explain the high assays reported in the State Papers. Unfortunately, this theory could not be substantiated in our analyses.

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GEOLOGY OF A VOLCANIC PILE AT CLAN LAKE, NWT

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INTRODUCTION

The Clan Lake Volcanic Belt, about 55km north of Yellowknife, was previously mapped by Jolliffe (1939) at a scale of 1 in. = 1/2 mi. and by Henderson (1976) at a scale of 1:125,000.

The rock units, part of the Archean Yellowknife Supergroup (Henderson, 1970) within the Slave Structural Province, were mapped at a scale of 1:10,000 for an M.Sc. Thesis. The general geology is that of a volcanic pile surrounded by younger turbidite metasediments intruded by metagabbro dykes and granitic rocks. Proterozoic diabase dykes crosscut these rocks.

DESCRIPTION OF ROCK TYPES

The volcanic pile has been subdivided into five lithologic units: andesite (unit 1), dacite (2), volcaniclastic rock (3), dacite/rhyolite (4), and basalt (5) (Fig. 1). The rock units are generally in stratigraphic order, though they interfinger with each other and individually include considerable lithologic variation and facies changes. Figure 2 is a facies model for these volcanic units, with the present-day configuration (minus folding and faulting) shown on the front side of the block diagram.

The oldest unit (1), is plagioclase phyric andesite and includes massive and pillowed flows (Fig. 3) containing numerous vesicles and quartz amygdules (up to 2 cm in size). Unit 2 has been subdivided into a massive dacite and a dacite breccia. The massive dacite is either aphyric or plagioclase phyric, in places with a few floating andesite clasts, more rarely with packed clasts. Elsewhere, the massive dacite lacks primary features and its mode of deposition is difficult to determine; probably it includes a combination of ash flow, ash fall and lava flow. The dacite breccia (Fig. 4) is confined to a prominent hill in the NW part of the volcanic pile. It is interpreted as crumble breccia of a dome complex. The breccia is poorly sorted, monomictic, clast-supported and has little matrix. Angular clasts, ranging from less than 1cm to more than a meter in size, are commonly cemented by pink carbonate. The breccia has crude layering due to variations in clast size and the presence of a few massive dacite layers (Fig. 5). The rock is additionally brecciated in shear zones. Unit 3, volcaniclastic rocks, includes interbedded diamictites, breccia, conglomerate, sandstone and pelite. The diamictite and breccia (Fig. 6), the predominant rock types, are debris flow deposits. Monomictic conglomerate (Fig.7) near the dome complex is fluvially reworked crumble breccia. Heterolithic conglomerate and rippled and crossbedded sandstone (Fig. 8) form other fluvial deposits. Unit 4, ryholite and dacite restricted to the western flank of the volcanic pile, comprises mainly ash fall and ash flow deposits. Massive and brecciated dacite forms a major component. Ash fall tuff (Fig. 9), predominantly at the top of the unit, has abundant plagioclase phenocrysts in a brownish grey, tuffaceous matrix. Ash flow tuff (Fig. 10 and 11) is a light grey tuffaceous rock with discrete, dark, lenticular zones (welded zones). Unit 5, the uppermost unit of the volcanic pile, is andesite and basalt. The lower part of this unit is predominantly meter-scale, well-bedded volcaniclastic rocks (Fig. 12), with minor interbeds of pillowed and layered flows, pillow breccia, and hyaloclastite (Fig. 13, 14, and 15). The clasts are reworked pillows, pillow breccia and layered flows; they are usually well rounded, sometimes white due to alteration by carbonate and sericite, and are commonly vesicular. Some clasts are concentrically zoned with vesicles (lava tube fragments?) and others are parallel zoned, layered flow fragments, (Fig. 16). The upper part of unit 5 is composed predominantly of pillowed (Fig. 17) and massive flows. The pillows vary in size and character, some being massive, some variolitic, and others vesicular, with vesicles either uniformly distributed, radiating, or concentrated at the pillow margins. One flow unit grades from small, non-vesicular pillows to large, vesicular ones (shallowing upwards). Airfall deposits are associated with all these volcanic units in varying amounts.

The turbiditic sediments (unit 6) are mainly greywackes and mudstones which, despite metamorphism and deformation, preserve numerous primary features within incomplete Bouma cycles. Some of the sedimentary structures are grading, crossbedding, scours, load and flame structures, ball and pillow structures, and convolute bedding, which are good top indicators; others are sandstone dykelets, climbing ripples, mud rip-up clasts and rare flaser bedding. The turbidites are mainly younger than the volcanic rocks though some similar older sediments are exposed within the core of an anticline at the SW end of the volcanic pile and also nearby between felsic volcanics of unit 3/4 and mafic volcanics of unit 5. The turbidites locally contain felsic volcanic clasts near the contact with the volcanics.

Metagabbroic dykes and other bodies intrude both the sediments and the volcanics. The rocks are now amphibolites, but still show primary, rhythmic layering.

Granitic rocks intrude both the sediments and volcanics and contain xenoliths of these rocks. The granites are pink to white and contain both biotite and muscovite.

Proterozoic diabase dykes crosscut all the above rock types.

DEFORMATION AND METAMORPHISM

The rocks have undergone a complex history of deformation and metamorphism. Two sets of moderately to steeply plunging major folds are present, a NE to N trending set and W to NW one. The time relationship of these sets is not clear. Changes in facing direction of both fold sets indicate earlier folding. Overprinting these folds are foliations developed during three periods of deformation. the earliest foliation is characterised by an easterly striking, discontinuous, spaced segregation cleavage (S_1), which is widespread in the felsic volcanics, rare in the mafic volcanics, and locally developed in the greywacke. S_1 is completely obliterated by later cleavages in the mudstone, except as inclusion trails in biotite porphyroblasts. The second foliation (S_2) strikes NW to locally NE across all the rock types. S_2 in the sediments is an axial planar cleavage to minor isoclinal to closed folds. The cleavage in the greywacke forms a closely spaced anastomosing or wavy pattern, and primary structures tend to be aligned subparallel. S_2 is expressed as a well-defined, slaty cleavage in the mudstone. In the felsic volcanics S_2 is a fine, continuous cleavage crosscutting the earlier S_1 segregation cleavage. In both the felsic and mafic volcanics primary features such as pillows, amygdules, and clasts are aligned parallel to S_2 to form a foliated and/or lineated fabric. The third foliation (S_3) is mainly confined to the turbidites, strikes NNE and is axial planar to minor isoclinal to closed folds. S_3 is dominantly a crenulation cleavage, though where S_2 is not present it is a fine, continuous cleavage in greywacke and a slaty cleavage in mudstone similar to S_2. S_3 is only locally seen in the felsic volcanics (unit 4) as a crenulation cleavage which is axial planar to chevron folds affecting S_2.

Proterozoic faults crosscut the area, with a major set trending NNE and a minor set trending E-W.

The rocks were metamorphosed to greenschist and lower amphibolite grade. Two major cordierite isograds run in a NNE direction through the sediments, outlining a zone of low grade, including sub-biotite, rocks in the center and higher grade rocks to the east and west. A narrow zone around the granitic intrusions in the west is cordierite-free, despite being above the cordierite isograd. Garnets are abundant within units 3 and 5 of the volcanics and are only locally apparent in the turbidites, both above and below the cordierite within the sediments, above the cordierite isograd. Andalusite and staurolite are sporadically distributed within the sediments, above the cordierite isograd.

Chlorite, muscovite and biotite grew throughout the last three deformation periods and cordierite, garnet, andalusite and staurolite grew during the end of and after the last deformation.

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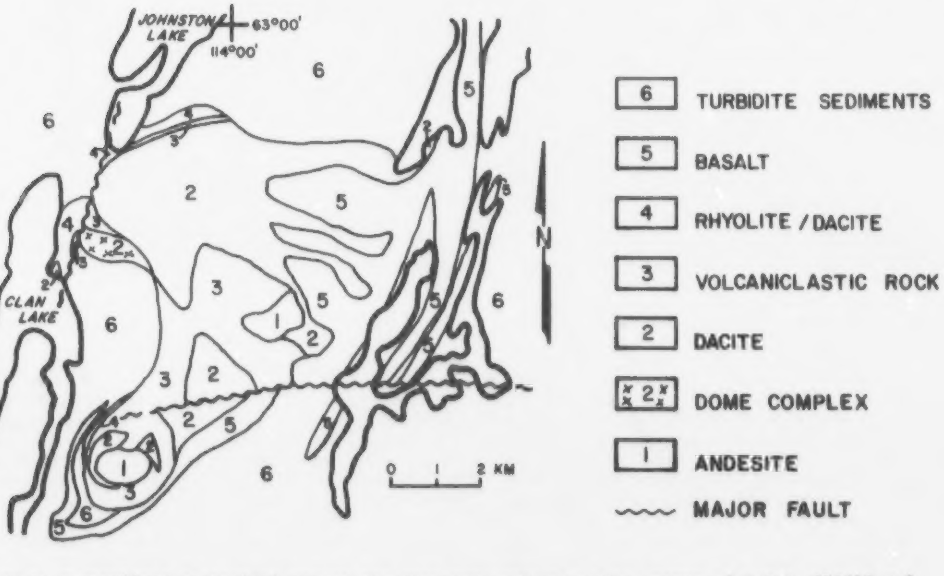


FIGURE 1: Generalized geological map of the Clan Lake volcanic pile, parts of N.T.S. 85I/13 and 85J/16. A detailed (1:10000 scale) geological map of this area is available from the Northern Affairs Program as E.G.S. 1983-5 (3 sheets, $15.00)

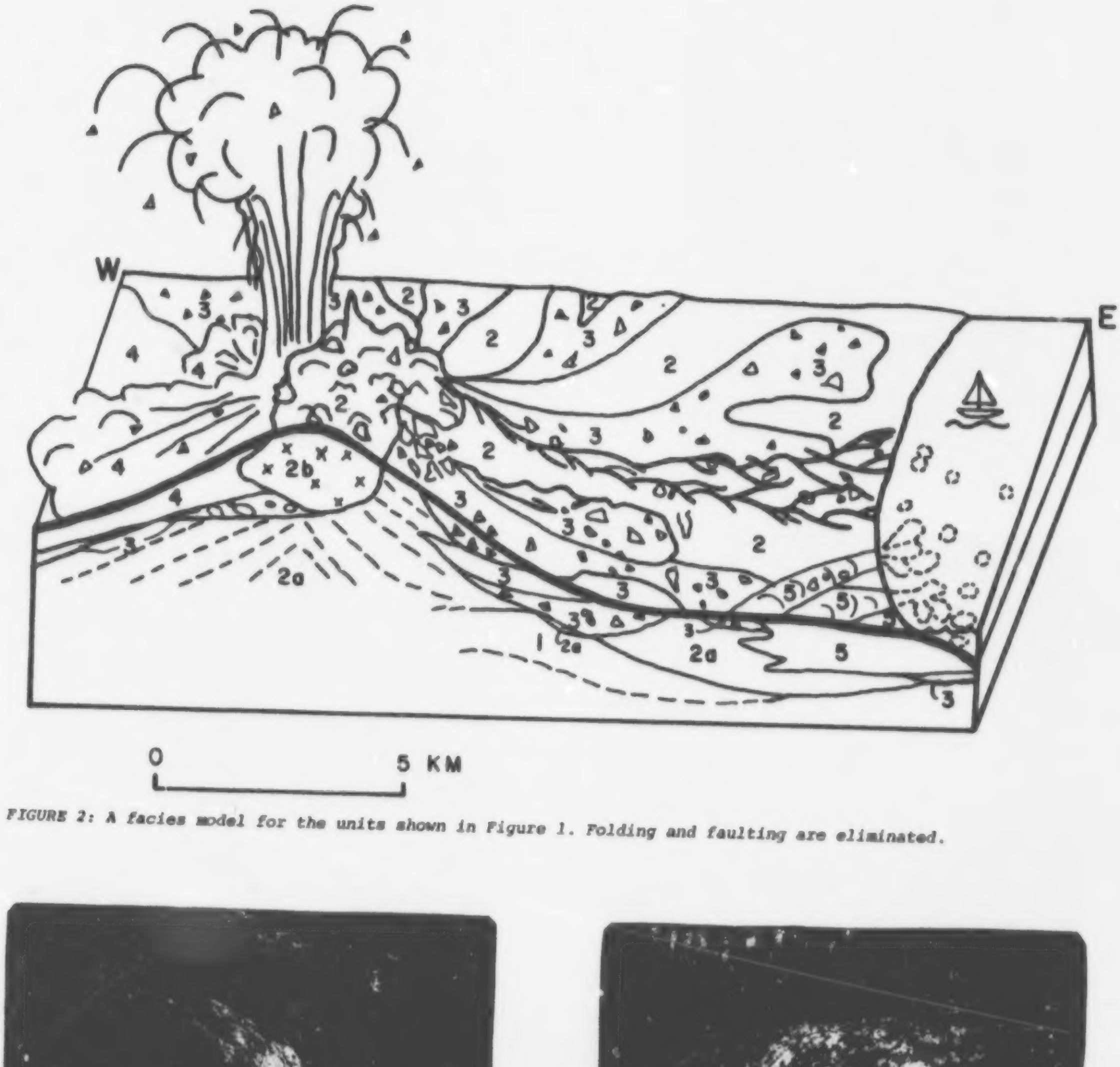


FIGURE 2: A facies model for the units shown in Figure 1. Folding and faulting are eliminated.

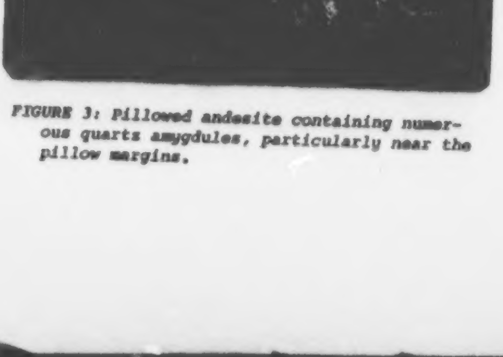


FIGURE 3: Pillowed andesite containing numerous quartz amygdules, particularly near the pillow margins.

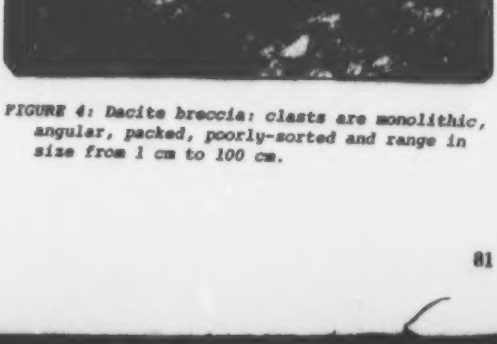


FIGURE 4: Dacite breccia: clasts are monolithic, angular, packed, poorly-sorted and range in size from 1 cm to 100 cm.

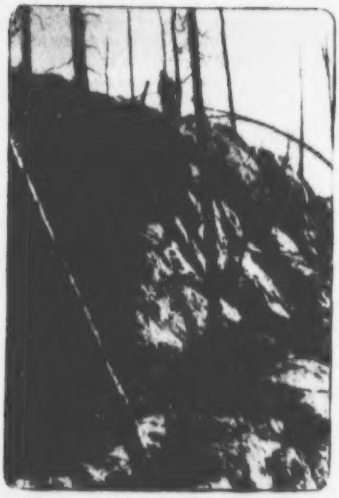


FIGURE 5: Dacite breccia in contact with a massive dacite layer.

FIGURE 6: Diamictite: clasts are semi-rounded to angular and range from 1 cm to 50 cm.

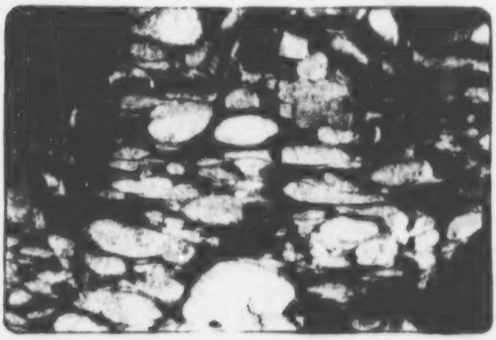


FIGURE 7: Monomictic conglomerate near the dacite dome complex.

FIGURE 8: Tuffaceous sandstone with planar cross-bedding (a) and ripples (b).

FIGURE 9: Crystal tuff containing abundant plagioclase phenocrysts in a brownish-grey tuffaceous matrix.

FIGURE 10: Ash flow tuff with fiamme.

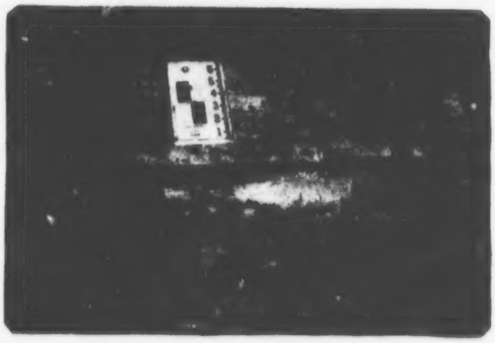


FIGURE 11: Ash flow tuff with dark, lenticular welded (?) zones.

FIGURE 12: Mafic volcaniclastic rock containing clasts (from pillowed and massive flows) that are subangular to rounded, fairly well-sorted, packed to floating and meter-scale bedded.

FIGURE 13: Mafic, layered flow or sill (?) in contact with mafic pillow breccia.

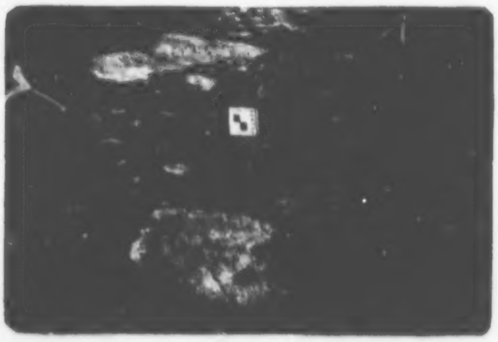


FIGURE 14: Pillow breccia: pillow fragments are floating in a hyaloclastic matrix.

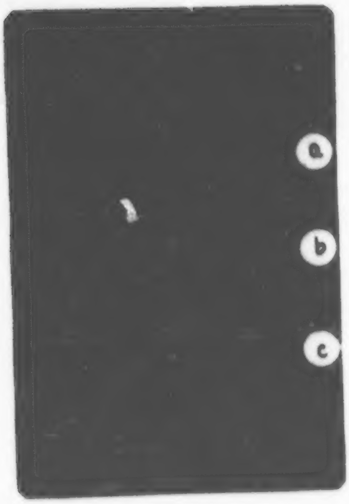


FIGURE 15: Mafic unit grading upsection from pillow lava (a) to pillow breccia (b) to hyaloclastite.

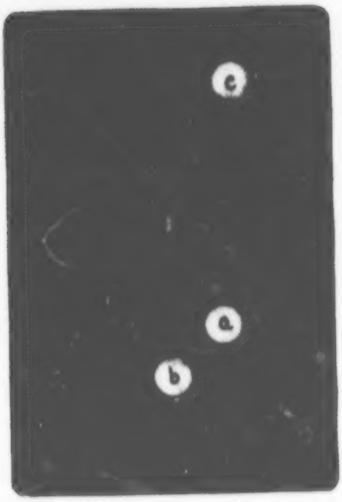


FIGURE 16: Mafic volcaniclastic rock containing clasts with numerous vesicles that are concentrically zoned (a), parallel zoned (b), and randomly distributed.

FIGURE 17: A thick unit of mafic pillow lava.

SEDIMENTOLOGY AND STRATIGRAPHY OF THE SILURIAN STRATA OF NORTHERN BRODEUR PENINSULA, BAFFIN ISLAND

by Franz Nentwich and Brian Jones
University of Alberta
Edmonton, Alberta

ABSTRACT

The Brodeur Group (Trettin, 1965) on northern Brodeur Peninsula comprises the Silurian Cape Crauford Formation and part of member B of the Baillarge Formation.

The Cape Crauford Formation consists of late Silurian partly dolomitic marine shelf limestones. Stratified and pipe breccia bodies occur in members A and B of the Cape Crauford Formation. Evidence currently available suggests that the brecciation resulted from interstratal karsting.

An unconformity at the top of member B of the Cape Crauford Formation attests to the subaerial exposure of this area in late Silurian time. It was during this period that the breccias were formed. The overlying member C of the Cape Crauford Formation consists of dolostone which is preserved only in the high-relief areas of the northwestern part of the peninsula.

ACKNOWLEDGEMENTS

We are grateful for the financial support from the Department of Indian Affairs and Northern Development (Contract YK83-84/078), the Boreal Institute for Northern Studies and the Natural Sciences and Engineering Research Council (Grant No. A6090 to Jones).

The Polar Continental Shelf Project of the Department of Energy, Mines and Resources is especially thanked for logistical aid over the past two field seasons. The Northern Non-Renewable Resources Division of the Department of Indian and Northern Affairs also provided valuable information in the form of oil and gas geological and geophysical reports.

Finally the writers thank Drs. H. Trettin (G.S.C.) and W. Gibbins (DIAND) for discussions on the geology of Brodeur Peninsula.

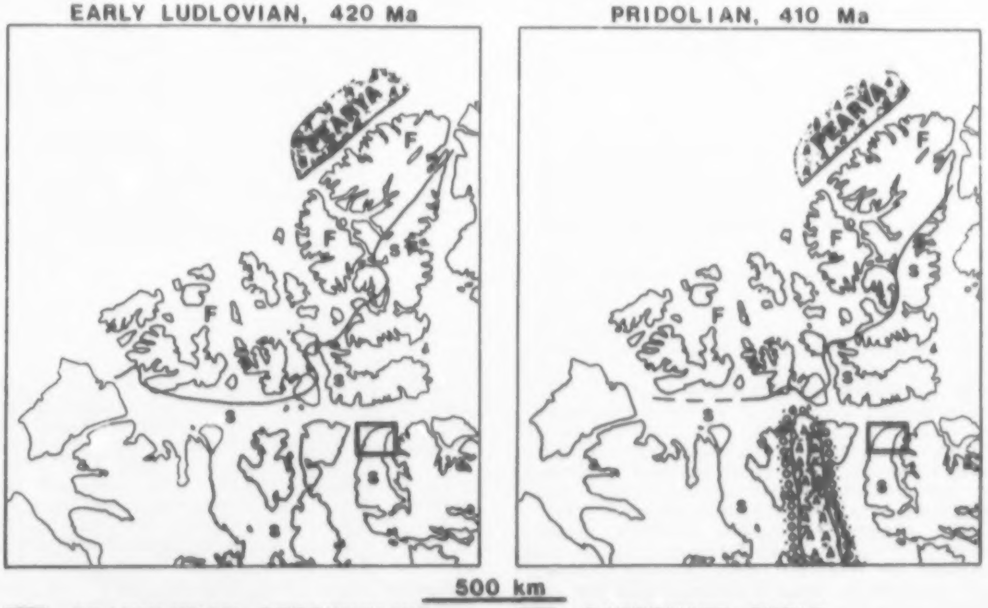
1. INTRODUCTION

A. Aims of study

This report summarizes the preliminary results of a Ph.D. thesis undertaken at the Department of Geology, University of Alberta under the supervision of Dr. Brian Jones.

The study was undertaken to investigate the sedimentology and stratigraphy of the Silurian strata of northern Brodeur Peninsula. Emphasis on sedimentary petrology will aid in the interpretation of depositional environments and permit determination of the diagenetic history.

Two field seasons have been completed; a final field season is planned for the summer of 1984. Completion of the thesis is expected by summer of 1985.



EARLY LUDLOVIAN, 420 Ma

PRIDOLIAN, 410 Ma

FIGURE 1: Locality of study area (outlined in bold) and paleogeographic setting of the Canadian Arctic Archipelago. Boothia Uplift is to the west of the study area. Circles and dots represent coarse clastics shed off the uplift.

B. Geographic and Paleogeographic Setting

A detailed paleomagnetic study by Lapointe and Dankers (1981) suggested that northern Brodeur Peninsula was about 10 degrees north of the equator during the Pridoli (latest Silurian). During the early Ludlovian the study area was situated on a broad carbonate shelf or platform about 250 km southeast of the shelf/slope break (Fig. 1). The Franklinian Geosyncline lay to the northwest and was an area of mainly silt and shale deposition. Paleocurrent indicators provide good evidence for the Pearya uplift to the northwest on Ellesmere Island. During the Pridoli there was a dramatic change in the paleogeographic setting with uplift of the Boothia Arch (Fig. 1) that exposed Precambrian terrain and resulted in the shedding of coarse clastics around its periphery.

C. Methods

To date, eleven stratigraphic sections (A to K) have been measured (Fig. 2).

Correlation between sections was achieved by using air photos and a sequence of 250 overlapping cliff photos that were taken in 1983 during a low-level Twin Otter flight. Conodonts are currently being processed and their identification will result in a more accurate time-stratigraphic framework.

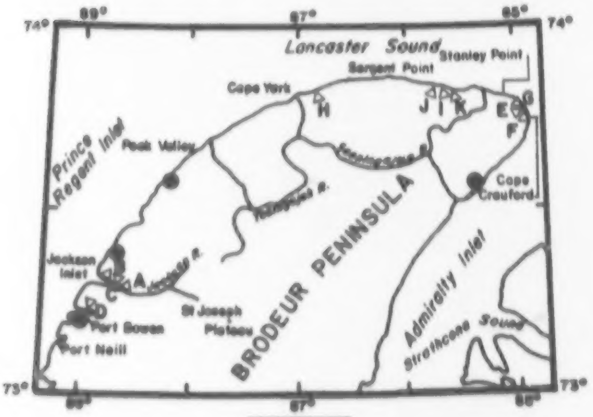


FIGURE 2: Locality of 1982 and 1983 measured sections (A-K). Proposed 1984 localities are shown as solid circles.

D. Previous Geological and Geophysical Investigations

Previous geological field work on northern Brodeur Peninsula is limited to that by Lemon and Blackadar (193), Norris (1963), Trettin (1965, 1969), Blackadar et al., (1968), Mayr and Harding (1971, unpublished), and Miall and Harding (1971, unpublished). Geological investigation prior to 1950 was summarized by Trettin (1969). A brief progress report was prepared by Heise (1970, unpublished) and Howell (1970, unpublished) prepared a brief report on photogeology.

Mineral exploration on Brodeur Peninsula has been conducted by Cominco Ltd and by Monopros Canada Ltd (Hudson Bay Mining and Smelting Co.) during 1982, but these works are classified company confidential and are thus unavailable.

Features of the breccia bodies of Brodeur Peninsula and their possible origin were discussed by Hentwich and Jones (1983, 1984).

Geophysical work in the area is limited to the offshore areas and includes that by Anonymous (1972), Ball (1973), Ball et al., (1973), Lack (1971, 1972a, 1972b, 1972c) and Pflueger (1974).

Norris (1963) measured 3 sections at Port Bowen, Jackson Inlet, and Sargent Point. Trettin (1965) measured the Cape Crauford section and designated it the type section of the Cape Crauford Formation.

II. STRATIGRAPHIC FRAMEWORK

A. Time-Stratigraphy

The Silurian strata of northern Brodeur Peninsula comprise the Cape Crauford Formation and Baillarge Formation (Fig. 3). Conodonts from rocks about 20 m below the base of the Cape Crauford Formation suggest a late Wenlockian to middle Ludlovian age for the Baillarge/Cape Crauford boundary (B.D.E. Chatterton, Univ. of Alberta, pers. comm., 1983).

The Cape Crauford Formation was subdivided by Trettin (1969) into the three informal members A, B, and C (Fig. 3). This study suggests that there is an unconformity at the top of member B.

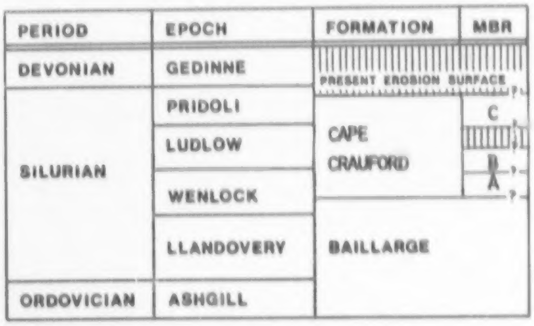


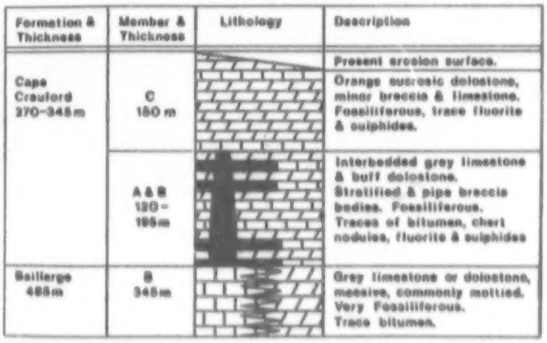
FIGURE 3: Tentative time-stratigraphic framework

B. Lithostratigraphy

The Baillarge Formation (Fig. 4) consists of massive bedded limestone or dolostone that is commonly mottled and fossiliferous. Solution breccias are rare in the Baillarge Formation. Members A and B of the Cape Crauford Formation lie conformably above the Baillarge Formation, but have not been differentiated in this study because they are difficult to distinguish outside the type section. Member A and B, which vary between 120 to 195 m in thickness, consist of interbedded grey limestone and buff dolostone. The Cape Crauford Formation is generally less fossiliferous than the Baillarge Formation, but some beds are fossiliferous. Members A and B contain both stratified and pipe breccias. Chert nodule beds are locally common.

The top of member B is an unconformity because member C beds lie undisturbed and in sharp contact above members A and B, which contain collapse zones up to a kilometre or more in width. It is clear that member C beds would have been involved in the collapse if they had been present at the time of collapse. An unconformity is therefore proposed on the basis of this evidence, but it is not clear whether the unconformity is a disconformity or a very slightly angular unconformity on a regional scale.

Member C, which is a distinctive orange-weathering sucrosic dolostone containing minor breccia, limestone, and sparse fossils, is up to 150 m thick. Traces of bitumen, pyrite, and purple fluorite are present in both the Cape Crauford Formation and Baillarge Formation.



Formation & Thickness	Member & Thickness	Lithology	Description
Cape Crauford 270-345m	C 150 m		Present erosion surface.
			Orange sucrosic dolostone, minor breccia & limestone. Fossiliferous, trace fluorite & sulphides.
	A & B 120-195m		Interbedded grey limestone & buff dolostone. Stratified & pipe breccia bodies. Fossiliferous. Traces of bitumen, chert nodules, fluorite & sulphides
Baillarge 485m	B 345m		Grey limestone or dolostone, massive, commonly mottled. Very Fossiliferous. Trace bitumen.

FIGURE 4: Columnar section showing formations, members, and brief descriptive notes. Unconformities indicated by wavy lines.

III. CORRELATION OF THE SILURIAN STRATA OF BRODEUR PENINSULA

A. Structural Correlation

Structural correlation (Fig. 5) of sections along the 170-km-long northwestern coast of Brodeur Peninsula between Port Bowen and Cape Crauford shows that the strata are flat lying in the line of section, with only minor folds. This will permit detailed study of lithofacies variations along the line of section.

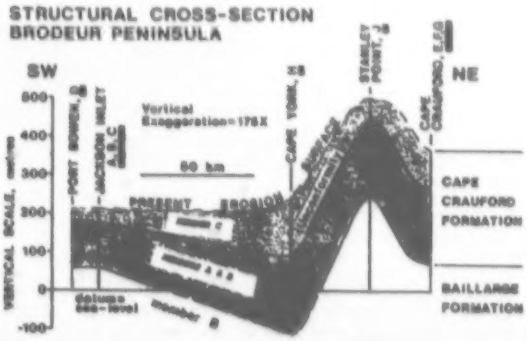


FIGURE 5: Structural cross-section, Port Bowen to Cape Crauford

B. Stratigraphic Correlation

Members A and B of the Cape Crauford Formation are more dolomitic and thinner in the Port Bowen and Jackson Inlet area than at Stanley Point and Cape Crauford (Figs. 6 and 7). The presence of oolites, desiccation cracks, and pisolites and the very sparse fossil content suggests a generally shallowing up sequence to the unconformity at the top of member B.

The largest breccia pipes are at Port Bowen. In the Stanley Point and Cape Crauford area, members A and B are considerably thicker and marine fossils, though rare, are present throughout the section. In general, the thickest stratified breccia units between Port Bowen and Cape Crauford are about 100 m below the base of the unconformity. The upper and lower boundaries of the breccia pipes occur at various stratigraphic levels. Convex-upward structures less than a metre across are localized in a zone about 40 m below the unconformity and occur immediately above a 15-m-thick pisolite zone at the Cape Crauford type section. These structures may be formed by dissolution/reprecipitation.

C. Stratified Breccias

A stratified breccia up to 22 m thick occurs in the Port Bowen/Jackson Inlet area, but it is not clear whether it is laterally continuous over the entire 17-km length of the cross-section (Fig. 8). Certainly it has been traced laterally for a distance of up to 3 km along the north shore of Jackson Inlet.

The stratified breccias of Jackson Inlet are clast supported. The clasts are commonly inversely graded or may consist of a lower breccia of pebble-sized clasts and an overlying breccia of cobble to boulder-sized clasts.

D. Pipe Breccias

Pipe breccias are present all along Brodeur Peninsula, but are most common in the Port Bowen/Jackson Inlet area. The pipes are collapse structures up to 100 m high, 20 m wide at the base and 10 m wide at the top. In the Port Bowen area they are so abundant and so close together that in places they form coalesced, laterally continuous breccia bodies hundreds of metres wide with a thickness of about 80 m. Typically the pipes sharply truncate the undisturbed strata, but locally they can be traced laterally into the pipes. The pronounced downturn of strata at the pipe boundaries and soft sediment deformation of some clasts in the breccia bodies indicate that the sediment was not entirely lithified at the time of brecciation. Indeed brecciation must have occurred prior to the deposition of member C because this member extends undisturbed over collapse zones hundreds of metres wide. A karstic origin for the breccia bodies is envisioned as having occurred when the area was subaerially exposed. The origin of the breccias must be related to the origin of laterally unbrecciated, correlative strata and, to a lesser extent, to regional lithofacies changes.

IV. ORIGIN OF BRECCIA BODIES

Norris (1963) and Trettin (1965) suggested that breccia bodies on Brodeur Peninsula formed due to the dissolution of interstratified evaporites. No relict

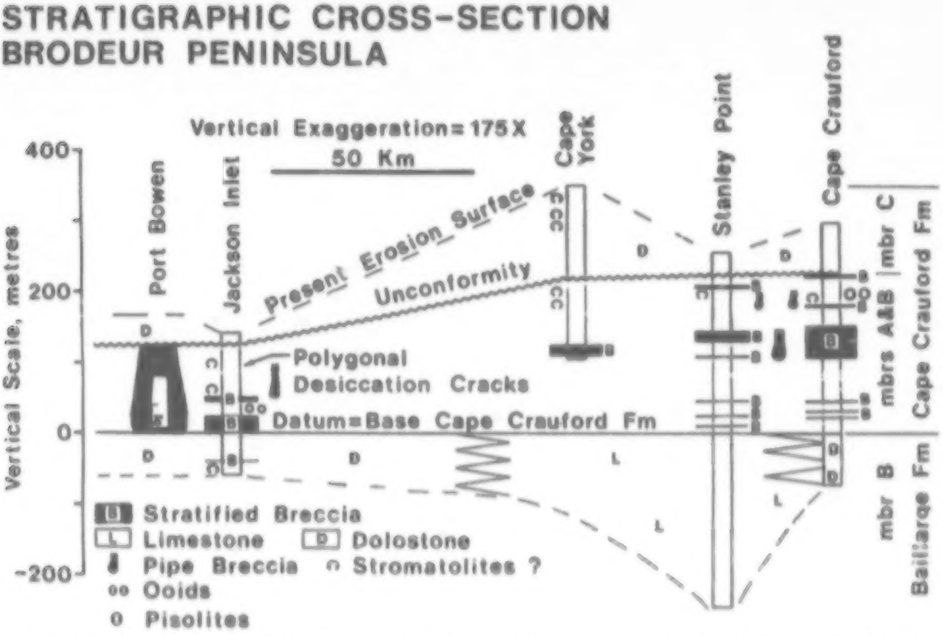


FIGURE 6: Schematic stratigraphic cross-section, Port Bowen to Cape Crauford, Brodeur Peninsula

aporites have been found during this study, although traces of possible gypsum molds were observed in samples taken near the top of member B. An alternative and currently favoured hypothesis is that limestone, and not evaporites, were dissolved to create the breccias.

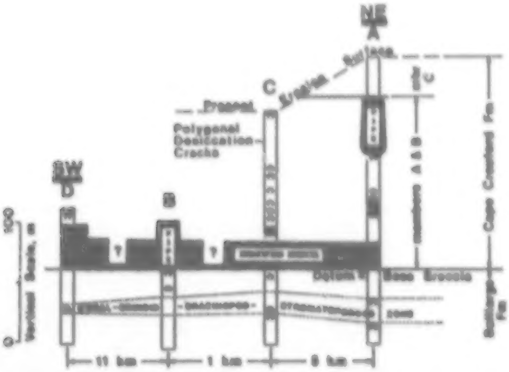


FIGURE 7: Schematic stratigraphic cross-section, Port Bowen to Jackson Inlet, Brodeur Peninsula. Unconformity indicated by wavy line.

V. PROPOSED FIELD WORK

The following sections will be visited in the 1984 field season (Fig. 2).

1. The Peak Valley locality is critical to correlation and to definition of lithofacies changes between the shallower water carbonates of the Jackson Inlet area and the slightly deeper-water carbonates near Cape Crauford.

2. A locality about 10 km north of Jackson Inlet. This will be useful in further defining the lateral continuity of the thick stratified breccia bodies and also provide further control on the correlation between Jackson Inlet and Cape York.

3. Port Bowen (south shore). Breccia pipes are spectacularly exposed at this locality.

4. A locality 28 km southwest of Cape Crauford. This locality, the type section of the Baillarge Formation, is included because there are solution breccias in the formation similar to those of the Cape Crauford Formation. The Baillarge breccias may bear heavily on the origin of the breccias in general, especially if the adjacent correlative strata are highly fossiliferous. It is also included here because a substantial section of the Baillarge Formation was encountered at Sargent Point.

5. Other localities may be visited dependent on the results of 1 to 4 above, on time remaining and on weather conditions.

VI. FUTURE LABORATORY WORK

Future laboratory work will include computer plotting of measured sections in order to effect detailed correlation of the Brodeur strata as well as to allow for comparison with the strata of Somerset Island.

The detailed sedimentology will be studied using lapped and stained rock slabs and stained and polished thin sections.

Few conodonts were recovered from 1982 samples. Larger conodont samples weighing about 5 kg were therefore taken during the 1983 season in an attempt to solve this problem. In addition, macrofossils will also be considered as potentially useful to time-stratigraphy.

An attempt to map the Cape Crauford Formation in the interior will be achieved by vertical and oblique (trimetrogon) air photographs in combination with photographs taken in the field.

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Contributions to the geology of the Northwest Territories
Volume 1, 1984, I.N.A.C. EGS 1984-6, p. 91-94

SUMMARY OF WORK DONE ON THE GEOLOGY OF THE ADAM AND KAMUT LAKE MAP AREAS (86 K/8, 86 K/9), NWT

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This report summarizes the results of our 1982 field season and discusses implications of these results regarding our understanding of the Great Bear Magmatic Zone and the Wopmay Fault Zone.

During the 1982 field season, work was done in the Adam Lake (86K/8) and Kamut Lake (86K/9) map areas. This work has completed the mapping of these two areas (1:25,000).

The first two base camps of the 1982 field season were in the Adam Lake area, where the relationship between rocks of the Great Bear Magmatic Zone and the Hepburn/Wentzel Batholith were studied. Some important observations and conclusions were derived from the study of this area: 1) the nature of transcurrent faults as they approach the Wopmay Fault zone (both NE-trending right laterals and NW-trending left laterals); 2) the nature of the contact between the Great Bear Magmatic Zone rocks and the Hepburn/Wentzel Batholith and 3) the occurrence of two large granitoid bodies that have a well-developed flat foliation and that contain large xenoliths of biotite schist. These plutons are cut by a large, undeformed syenogranite pluton (the Adam granite).

Wopmay Orogen is cut by a system of conjugate transcurrent faults. The Great Bear magmatic zone is dominated by northeast-trending, right-lateral transcurrent faults that bend, splay, and die out as they approach the Wopmay Fault zone (Fig. 1). Detailed mapping has shown that the right-lateral transcurrent faults that cut the Great Bear Zone and the left lateral faults that cut the Hepburn/Wentzel Batholith bend into parallelism with the Wopmay Fault Zone.

The Tilchuse Fault (Fig. 1) has been estimated to have about 20 km of separation along it in the Conjurer Bay area, but as it approaches the Wopmay Fault Zone, separation decreases and the fault bends into parallelism with the Wopmay Fault zone.

South of the Tilchuse Fault the contact between the Great Bear Magmatic Zone and the Hepburn/Wentzel Batholith is an unconformity. Thin lenses of conglomerate extend westward from the fault zone and are interbedded with mudstone and siltstone of the Dumas Group. North of the Tilchuse Fault the contact between the Great Bear Magmatic Zone and the Hepburn/Wentzel Batholith is not well exposed and is likely a faulted contact; silicification and development of a flattening foliation in Dumas Group rocks is common. This suggests that the displacement on the Tilchuse Fault was taken up along the Wopmay Fault Zone or that it diminished as it approached the zone. In any case, the preservation of the unconformity south of the Tilchuse Fault and the highly complex geology north of it (Fig. 3) indicate that the Tilchuse is a major fault and domain boundary within the Great Bear Magmatic Zone.

In the southwestern portion of the Adam Lake map area two deformed granitic plutons crop out (Fig. 2). The plutons are anomalous compared to other plutons of the Great Bear Magmatic Zone in that they possess a strong metamorphic foliation that defines a broad domal structure; the foliation dies out to the north. The foliations are generally shallowly dipping and contain near-horizontal mineral lineations. The foliation has been folded about NW-trending axes, as have the supracrustal rocks. The foliation is defined by alignment and flattening of alkali feldspar, quartz, and biotite.

The development of the foliation is tightly bracketed by other events in the Great Bear Magmatic Zone. The foliation is definitely pre-Adam granite as it is intruded by the undeformed Adam Pluton (1840 m.y.), and along the contact zones blocks of deformed granite are found within the Adam Pluton. In addition, the foliation in the granites is folded about NW-trending axes, as are all rocks within the Great Bear Magmatic Zone (with the exception of the late granites such as the Adam Pluton). Thus, the development of the foliation must have occured soon after intrusion of the granite. A preliminary U-Pb zircon age of 1865 m.y. for the deformed granite supports this.

The flat foliation and the observation that its development becomes less and less pronounced and eventually absent to the north is consistent with the foliation representing a flat surface of deformation, perhaps a detachment surface. In the volcanic rocks, structurally above the foliated granite, are zones in which narrow (0.1 to 0.5 meter) shear zones are developed. In an alkali-feldspar megacrystic porphyry, individual megacrysts on the order of 2-3 cm in length have been lengthened to 10-12 cm. This is consistent with the zone of well-developed flat foliation being a detachment surface on a lower plate, characterized by discrete, widely spaced ductile shear zones. Further work to the south will test this hypothesis, but in any case the presence of this sort of metamorphic core complex must be considered in any model for the origin of the Great Bear Batholith.

The other major base camp of the field season was on Jaciar Lake, where mapping of the northern part of the Kamut Lake map area was completed. Two major discoveries were made: 1) a large sliver of strongly foliated basement rock is exposed within the volcanic rocks of the Sloan Group; and 2) the contact between a late granite (Spence Pluton) and the Kamut Pluton is very flat (dips 12 degrees to the north), which documents the post-folding, sheet-like nature of the late granites in the Great Bear Magmatic Zone.

To the east of Jaciar Lake is a large exposure of strongly deformed, tourmaline-bearing megacrystic granitoid (Fig. 3). Deformation is restricted to north-trending ductile shear zones in which the rocks have been isoclinally folded; in places, a well-developed mylonitic fabric is present. Alkali feldspar megacrysts, some on the order of several cm long, have been strongly flattened and sheared out. A sample from this outcrop has been dated at 1930 m.y., considerably older than magmatism in the Great Bear Magmatic Zone (1860 m.y.) or the Hepburn/Wentzel Batholith (1880-90 m.y.). The nature of the contact with the structurally higher Sloan Group rocks is typically not well exposed; however, it is believed to be a thrust fault. To the south the same deformed basement is juxtaposed against a thick, recumbently

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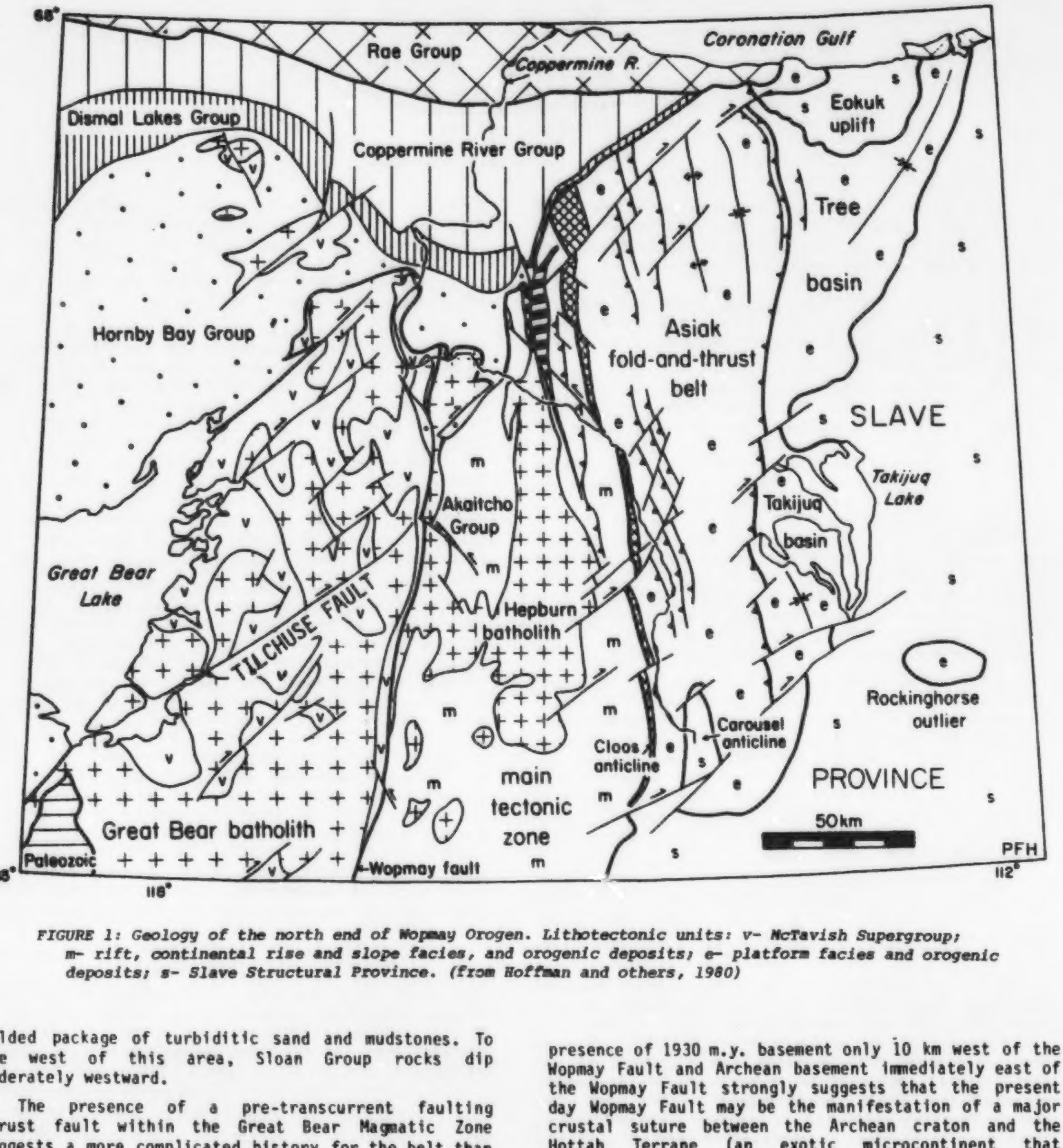

FIGURE 1: Geology of the north end of Wopmay Orogen. Lithotectonic units: v- McTavish Supergroup; m- rift, continental rise and slope facies, and orogenic deposits; e- platform facies and orogenic deposits; s- Slave Structural Province. (from Hoffman and others, 1980)

folded package of turbiditic sand and mudstones. To the west of this area, Sloan Group rocks dip moderately westward.

The presence of a pre-transcurrent faulting thrust fault within the Great Bear Magmatic Zone suggests a more complicated history for the belt than was previously thought. Further detailed structural and stratigraphic work to the west should be completed to understand this zone.

The other major discovery was the nature of the contact between the Spence Pluton and the Kamut Pluton. The Kamut Pluton has been folded about NW-trending axes, as have the supracrustal rocks. The Spence Pluton was intruded as a sheet-like mass whose lower contact dips about 12 degrees to the north. This confirms the idea that the late K-rich plutons were intruded after folding, perhaps related to crustal thickening during folding.

It appears now that the Wopmay Fault must represent a fundamental crustal discontinuity that was developed prior to eruption and intrusion of rocks within the Great Gear Magmatic Zone. The presence of 1930 m.y. basement only 10 km west of the Wopmay Fault and Archean basement immediately east of the Wopmay Fault strongly suggests that the present day Wopmay Fault may be the manifestation of a major crustal suture between the Archean craton and the Hottah Terrane (an exotic microcontinent that collided with the Slave Craton between 1900-1885 m.y. ago that is exposed to the west of Hottah Lake). This idea is further supported by the paucity of Great Bear Magmatic Zone plutons east of the fault and the observation that the Wopmay Fault has served as a domain boundary between zones of right and left lateral transcurrent faulting.

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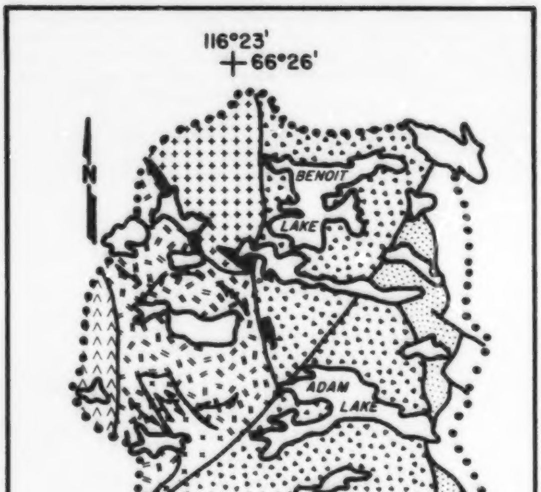
116°23'
66°26'
N
BENOIT
LAKE
ADAM
LAKE
0 km 5
Schist inclusions
Sloan Group volcanics
Foliated syenogranite
Foliated megacrystic granite
Unfoliated quartz diorite, Benoit Pluton
Unfoliated syenogranite, Adam Pluton
Dumas Group siltstone and conglomerate
Wentzel Batholith (undifferentiated)
strike and dip direction, foliation
limit of mapping

FIGURE 2: Generalized geological map of the southern part of the Adam Lake map-area (86K/8) and the northern part of 86K/1 showing major structural features.

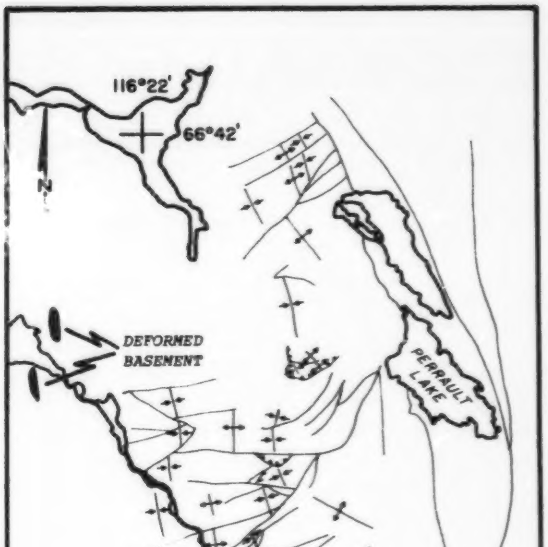

FIGURE 3: Generalized structural map of parts of the Adam Lake and Kamut Lake map-areas showing the location of the basement slivers. Note complexity of structure north of the Tilchuse Fault. Co-ordinates are centred on Kamut Lake.

Contributions to the geology of the Northwest Territories
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MISSISSIPPI VALLEY TYPE LEAD-ZINC DISTRICTS OF NORTHERN CANADA *

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ABSTRACT

Mississippi Valley type (MVT) deposits account for all of the lead, zinc, cadmium and a significant amount of the silver currently produced in Northern Canada. This production comes from deposits associated with a Middle Devonian barrier reef complex of the Pine Point District, the Polaris deposit in Ordovician Thumb Mountain Formation in the Cornwallis Lead-Zinc District and the Nanisivik deposit in Helikian (Proterozoic) Society Cliffs Formation on Northwestern Baffin Island. The Cordillera of Northern Canada contains important undeveloped MVT deposits in the Robb Lake, Gayna River, Bonnet Plume River and Godlin Lakes districts.

These deposits can all be related to major structural elements, (basement structures and/or unconformities) extensive shale source rocks and solution breccia or karst development. Hydrocarbons, evaporites and dolomitization are generally present, but have variable aspects.

Future exploration successes are most likely in known districts and extensions of these districts. IP, EM, gravity and geochemistry ("zinc-zap") have been successful exploration techniques in the Pine Point, Nanisivik, Cornwallis and Mackenzie Mountain areas respectively. Other areas with geological potential, but very little exploration to date, are the carbonates of the Franklin Miogeosyncline (Ellesemere Island), the Northern Interior Plains, and the Clyde River Fold Belt of the Central Baffin Island. Potential for MVT deposits is more uncertain in carbonates of the Arctic Platform (Brodeur Peninsula of Northwestern Baffin Island and Victoria and Banks Islands of the Western Arctic) and cratonic basins, the Foxe Basin and in the Northern Hudson Bay Basin (southern and western Southampton Island).

INTRODUCTION

Northern Canada

Some may consider all Canada 'Northern', but, the author will restrict Northern Canada to the area north of latitude 60 degrees north, which comprises the Yukon and Northwest Territories, plus the area of Northern British Columbia north of 56°30'N, where substantial tonnages of lead-zinc mineralization have been found (Figure 1). Northern Canada contains more than half a billion metric tonnes of lead-zinc mineralization in three important types of deposit: Mississippi Valley type (MVT), shale-hosted type (SHT) and volcanogenic type (VGT) (Table 1). Important vein and skarn deposits occur, but they are insignificant in terms of lead and zinc potential.

TABLE 1 MAJOR Pb-Zn TYPES OF N. CANADA

					Contained Metal Mmt			
TYPE	Mmt*#	$Pb	$Zn	$Cu	Pb	Zn	Cu	TOTAL
MVT	199.6	2.0	6.9		4.0	13.8	-	17.8
SHT	302.3	3.2	5.7	-	9.7	17.2	-	26.9
VGT	52.8	0.9	7.4	1.3	0.5	3.9	0.7	5.1

*Millions of metric tons or tonnes = Mmt
#Production plus reserves (TABLES 1-3)

Volcanogenic deposits in remote parts of the Slave and Churchill provinces of the Precambrian Shield await the development and construction of cost efficient transportation systems and power supplies.

Large tonnages of lead-zinc mineralization occur in shale-hosted deposits in the MacMillan Pass and Howard's Pass areas along the Yukon-N.W.T. boundary, in the Anvil District of South-Central Yukon and the Akie River District of Northern British Columbia. Remoteness, lack of infrastructure and expensive milling related to fine grain [illegible] are detriments to their development. The Yukon Territory's major producer, the Faro Mine in the Anvil District, was closed in 1982 until economic conditions improve.

Currently all the lead, zinc, cadmium and a significant amount of the silver produced in Northern Canada come from three MVT deposits, the Nanisivik and Polaris mines in the High Arctic and open pit mines near Pine Point south of Great Slave Lake (Figure 1). The value of lead and zinc in ores produced from these deposits amounted to 70 per cent of the total value of N.W.T. mineral production in 1981 and 1982.

These operations were developed and continue to operate even during times of low metal prices, because they are (1) large, (2) high grade, and (3) accessible to relatively low cost transportation and (4) the deposits are amenable to cost-effective mining and milling methods. The Polaris deposit in the Cornwallis Lead-Zinc District is undoubtedly one of the world's largest single deposits in terms of contained zinc. Both Polaris and Nanisivik have average grades and cut-off grades two or more times their counterparts elsewhere in the world. Sales from early shipments of high grade 'direct shipping ore', averaging 45 to 50% Pb + Zn from Pine Point, are rumored to have paid for their mill before it began operation in late 1965. Jackson and Folinsbee (1969, Table 1) list details of early production and earnings. The Nanisivik mine is less than 3 km and the Polaris mine less than one km from tidewater and low-cost albeit seasonable deep-sea transportation. Innovative mining techniques, e.g. dry mining in permafrost at

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* *Reprinted from: International Conference on Mississippi-Valley-Type lead-zinc deposits, proceedings volume,University of Missouri-Rolla, Rolla, Missouri, 1983, p. 403-414*

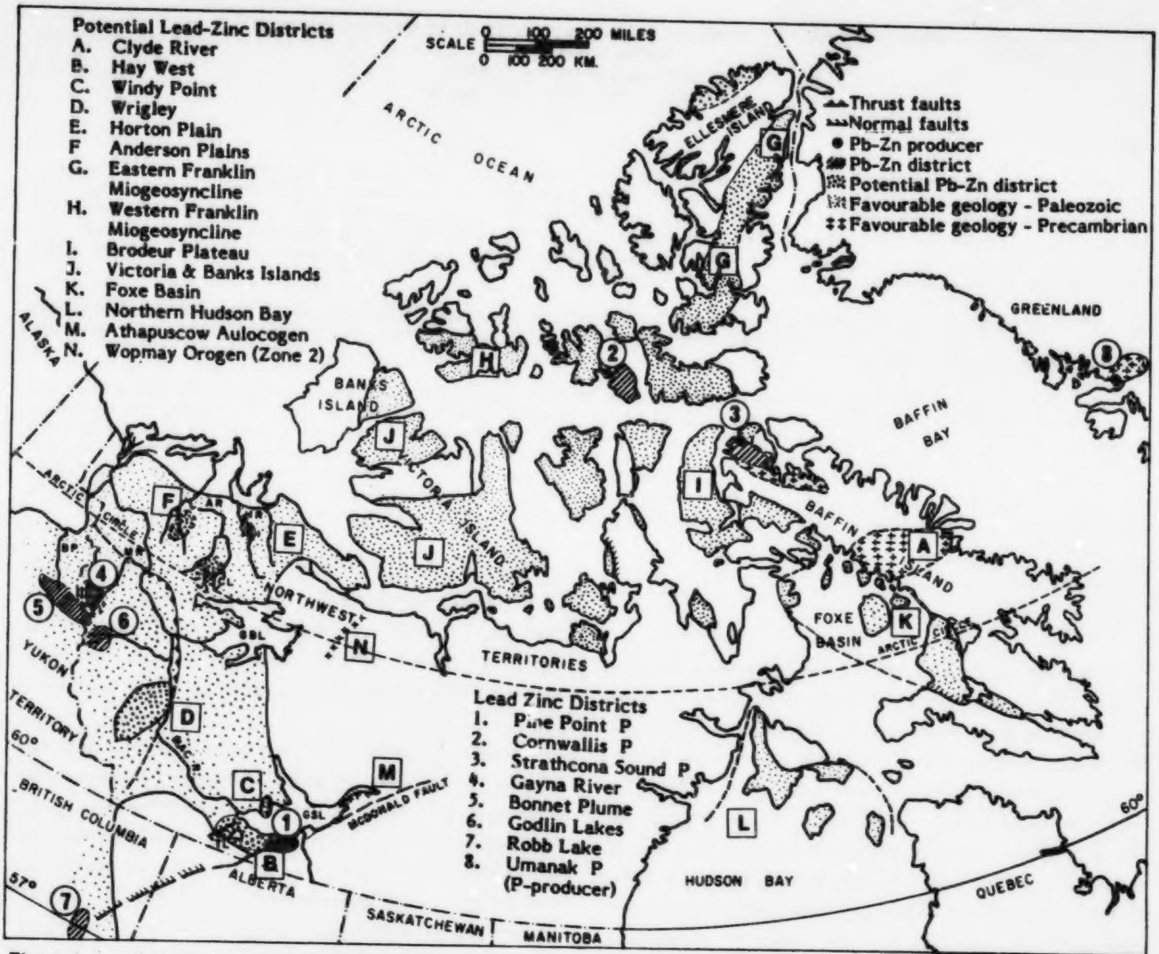


Figure 1 Northern Canadian MVT Districts (circles) and Potential Districts (squares)

Nanisivik and Polaris, and high concentrate recoveries, approaching 98% for zinc and 93% for lead at Nanisivik, have led to cost-effective operations.

Mississippi Valley Type Deposits and Districts

MVT deposits can be defined as strata-bound deposits of lead and/or zinc minerals in carbonate rocks. In Northern Canada the carbonate host rock is normally brecciated dolomite with abundant secondary sparry dolomite. Major structural elements control depositional environments and are empirically related to mineralization. Faults, arches and unconformities, that control the development of facies changes, karsting, reef complexes, deposition and solution of evaporites and accumulation of hydrocarbon, are normally present, (see Anderson and MacQueen, 1982 for a recent review of MVT charateristics and genesis).

Barite and fluorite, that are common in many MVT deposits, are generally rare to absent in MVT deposits of Northern Canada. Lead-zinc ratios, minor elements, accessory minerals, textures and exploration methods are a few of the many parameters that vary among MVT deposits. Since recognition as a unique type of deposit, concerted efforts to identify the source of metals and processes that form MVT deposits have not produced universally accepted answers. Much greater progress has been made in the discovery of MVT deposits in Northern Canada and other parts of the world. Reserves in the Pine Point area have increased from a few tonnes in surface showings, brought to the attention of prospectors on their way to the Klondike by local Indians in 1898, to several million tonnes when mining operations began in 1964, to several tens of millions of tonnes known today. Additional tonnage has been discovered in several new MVT districts of Northern Canada (Table 2). Grades are higher and tonnages comparable with districts in the Mississippi Valley of the USA (Table 3). Most of the differences can be attributed to the large, lead-rich deposits of Southeast Missouri. The low-grade deposits of the Eastern Tennessee District would not be considered economically significant in any of the Northern Canadian Districts.

TABLE 2 MINERAL INVENTORY MVT DISTRICTS - N. CANADA

DISTRICT	Mmt	%Pb	%Zn	Contained Metal Mmt. Pb	Contained Metal Mmt. Zn
PINE POINT	94.5	2.5	6.2	2.4	5.8
CORNWALLIS	24.1	4.2	13.8	1.0	3.3
NANISIVIK*#	6.4	1.2	11.5	0.1	0.7
GAYNA RIVER	50.0	0.3	4 7	0.2	2.4
BONNET PL.*	10.9	-	8.0	-	0.9
GODLIN LK.*	8.2	2.6	5.4	0.2	0.4
ROBB LAKE*	5.5	2.3	5.0	0.1	0.3
TOTAL (AVE)	200	(2.0)	(6.9)	4.0	13.8

*Single deposit #By-product silver

TABLE 3 ORES OF MAJOR MVT DISTRICTS OF THE U.S.A.

DISTRICT	Mmt	%Pb	%Zn	Contained Metal Mmt Pb	Contained Metal Mmt Zn
AUSTINVILLE	25	0.7	3.7	0.2	0.9
E. TENNESSEE	50	-	4.0	-	2.0
ILL.-WISC.	100	0.5	5.0	0.5	5.0
TRI STATE	500	0.6	2.3	3.0	11.5
SE. MISSOURI:					
OLD LEAD BELT	340	3.0	-	10.2	-
VIBURNUM	*420	6.0	1.0	25.2	4.2
TOTAL (AVE)	1435	(2.7)	(1.6)	39.1	23.6

From Barnes et al., 1982 *Estimated

PRODUCING MVT DISTRICTS OF NORTHERN CANADA

Pine Point District.

More than 50 MVT deposits have been found on the south side of Great Slave Lake (Figures 1 and 2), principally within a 60-km-long section of a Middle Devonian barrier reef complex averaging 8 to 10 km wide and trending north 65°east. Aeromagnetic maps show that this trend parallels the southwesterly extension of the McDonald-Hay River fault zone in the Precambrian basement. According to Belyea (1971).

> "Normal faults and small horst and graben structures provide the most satisfactory explanation for the varying distribution and thickness of most Middle Devonian rock units and may explain the location of some reef developments. The repetition of the same lineaments throughout Middle Devonian deposition suggests successive movements along the same faults zones."

The reef separates a thick section of evaporites (Muskeg Fm.) to the south from thin, open marine carbonates and calcareous shales to the north (Figure 3A and B). The following is a brief summary of the geological history of the reef complex by Skall (1976), (a more detailed review is given in Skall (1975)).

> "The start of the barrier is envisaged by a gentle arching of the underlying Keg River limestone that initiated reef growth at early Givetian time. As the reef grew northward, a second tectonic movement subjected the backreef area - now occupied by the Muskeg evaporites - to a slightly higher rate of subsidence that caused extensive pan areas in which evaporites precipitated. During this time, early diagenetic dolomitization took place due to reflux of Mg-rich brines from the evaporite pans, which converted the lower part of the barrier to a fine sucrosic dolomite. This development came to a halt with renewed tectonic movements that caused the Main and North Hinge structures. The evaporite pans were now covered by extensive backreef limestone and early diagenetic

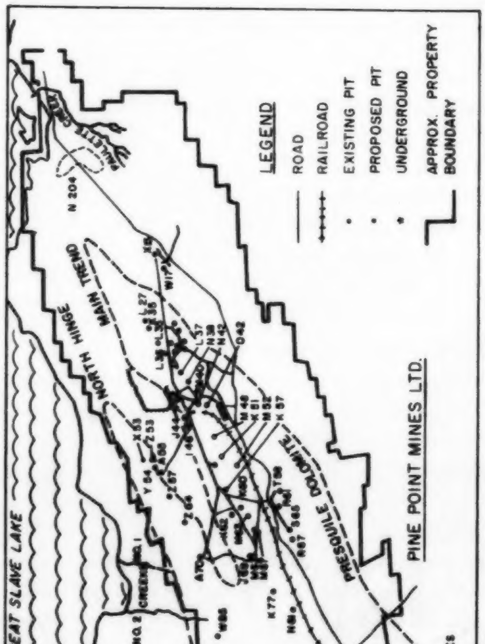


Figure 2 Map of Pine Point District showing MVT Deposits

dolomitization ceased, leaving the upper part of the barrier undolomitized. At the time, from middle to late Givetian, a marine regression elevated the barrier at least 100 feet above sea level and exposed the carbonates to karsting and erosion, which produced a residual soil of waxy green clay and limestone rubble. Karsting was particularly intense along the Main and North Hinge fracture zones, and probably caused most of the solution collapse structures that were favoured as loci for later precipitation of sulphides. During late Givetian, a marine transgression covered the Pine Point barrier with renewed carbonate sedimentation of the Slave Point group. The timing for the dolomitizing process that caused the coarsely crystalline Presquile is uncertain. It probably took place in past middle Devonian time, with warm, basin-derived Mg brines spreading along the Main and North Hinge and altering the vulnerable limestone of the upper barrier to coarsely crystalline Presquile dolomite. Mineralization followed, but remained independent from processes related to the formation of the Presquile dolomite."

Ore deposits are confined to the reef, but occur in both Presquilized and non-Presquilized parts (Figure 3A). Two types of ore bodies are recognized, those of the prismatic-type are collapsed, equidimensional or pipe-like caverns (X-15 and A-70, Figure 3A) and tabular or run-types, which are represented by relatively thin, elongate or tube shaped stratabound cavern systems (L-37 and Z-53-N of Figure 3A). The later are becoming increasingly important as many of the prismatic-type have been mined out.

The M-40 deposit is a run-type deposit that has been mined from underground workings, however, all other deposits mined to date are open pits. N-204 represents a possible third type of deposit. It is a flat pancake-shaped low-grade deposit that occurs low in the section (Figure 3A), but lies close to the present surface on the eastern end of the westerly-plunging reef trend (Figure 2). The size and grade of N-204 are believed to be comparable with deposits of the Eastern Tennesse District, however, they are not 'ore' at Pine Point.

The paucity of outcrop precludes use of conventional prospecting techniques and grid drilling and geophysical work directed by geological concepts will continue to play the most important role as deeper targets are probed. The induced polarization or IP method has been the most successful and cost-effective geophysical tool in the Pine Point District (Lajoie and Klein, 1979).

Since 1966, Pine Point Mines Ltd. has maintained ore reserves of 36 ± 2 million tonnes, while milling 3 to 3.5 million tonnes per year. Since 1975, Westmin Resources Ltd. and their partners have extended the area of known MVT mineralization westward onto their property where the main hinge zone occurs at depths of 175 to 325 metres (Spencer et al., 1980). Seven separate zones containing an aggregate geological reserve of 7.2 million tonnes grading 10% Pb + Zn have been reported by Westmin Resources Ltd.

The Jackson and Beales hypothesis. This hypothesis calls for dewatering and metal-rich brine formation in an adjacent shale basin, specifically 'the South Mackenzie Shale Basin', as a source of metals for MVT mineralization in Pine Point deposits. Jackson and Beales' (1967) hypothesis has certain appealing features, for example; the universality (in Northern Canada at least) of large amounts of shale somewhere in the stratigraphic package, separated from carbonate host rocks by overlying, underlying or lateral facies changes. Indeed, "It has stood the test of time," (i.e. it's still popular at arm-waving sessions, although the term 'stratafugic fluid' never really caught on), and evolved from hypothesis, to theory, to the accepted model of many geologists. The author feels there are a number of problems in the idea as applied to Pine Point, if not elsewhere, and prefers to consider their concepts at the hypothesis level.

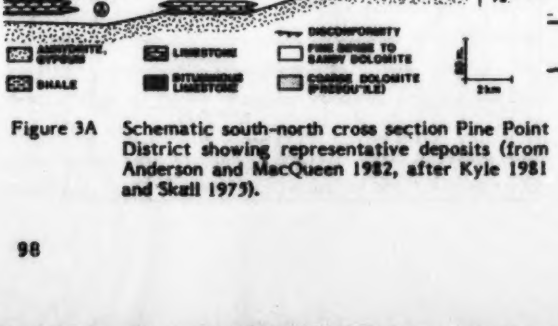
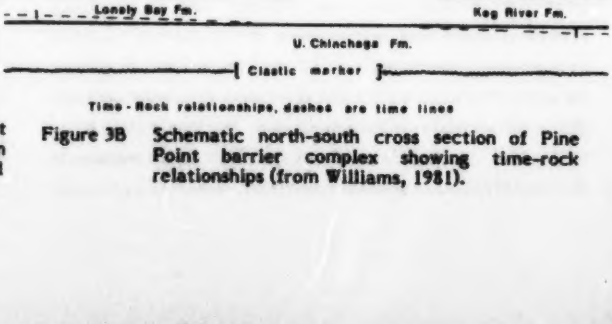


Figure 3A Schematic south-north cross section Pine Point District showing representative deposits (from Anderson and MacQueen 1982, after Kyle 1981 and Skall 1975).



Time - Rock relationships, dashes are time lines

Figure 3B Schematic north-south cross section of Pine Point barrier complex showing time-rock relationships (from Williams, 1981).

Their comment, "Clearly, proof of a sedimentary diagenetic genesis of the Pine Point and similar ore bodies has not yet been established", remains valid.

The large Middle Devonian 'Mackenzie Shale Basin', shown in Figure 1 of Jackson and Beales, 1967 and Jackson and Folinsbee, 1969, does not appear in the diagram that their Figure 1 is based on. Figure 5-11D of Grayston et al., 1964 shows only a narrow belt of 'thin carbonates' running along the northern margin of the barrier complex described in their text as off-reef carbonates. The Horn River Fm, consisting of dark shales interbedded with limestones (Norris, 1965) would appear to be the most likely manifestation of the 'Mackenzie Shale Basin'. However, it only reaches significant thickness in a small area centered on the Deep Bay Bank at the westernmost end of Great Slave Lake, some 100 to 200 km northwest of Pine Point (Williams, 1981, Map 6). Macqueen et al., 1975 collected samples of shales in this area and noted high metal values, which they correlated with organic carbon. North of Deep Bay, the Horn River Fm. thins rapidly as the Horn River Shelf is approached (Williams, 1981). To the south along the seaward edge of the barrier complex, shaley carbonates (Buffalo River Shale etc.) could only accumulate as mud banks in the shelter of the barrier's sea wall (Figure 3B, from Williams, 1981, time lines 2-5).

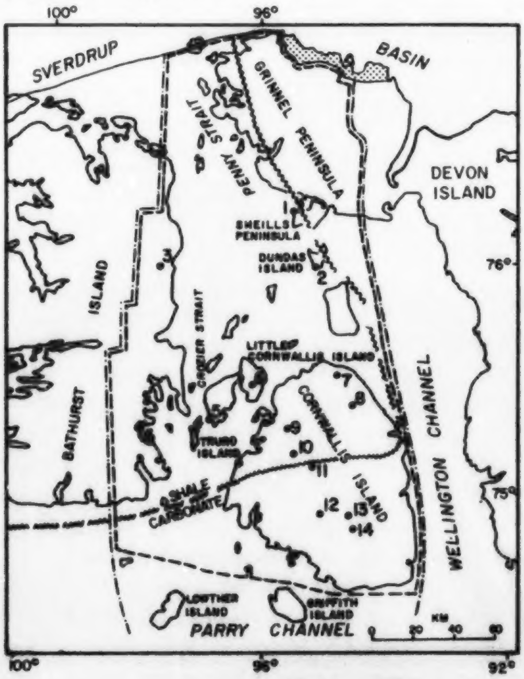


Figure 4 Map of Cornwallis District showing known MVT deposits and showings (from Kerr, 1977b)

Jackson and Beales (1967, Figure 1) seem to be oblivious to the existence and implications of Middle Devonian patch reefs, containing Presquile alteration and lead-zinc mineralization, that occur near Windy Point on the north shore of Great Slave Lake (Norris, 1965) and within their Mackenzie Shale Basin. Perhaps they might also consider the thick section of Upper Devonian Hay River-Fort Simpson shales that occur to the west of Pine Point as part of their genesis.

Kyle (1980, 1981) discussed some of the chemical problems and alternatives of the J & B hypothesis, as well as considering source rocks other than shale relative to Pine Point and other MVT areas. Kyle (1980,1981) suggests that concepts of multiple phases of metal enrichment and the exhalative supply of metals to the sea floor along hinge zones should be considered. The latter concept could probably be developed further in combination with some of the original concepts of Campbell (1966).

The Cornwallis District

The Cornwallis Lead-Zinc District (Figure 4) coincides with the northern half of the Cornwallis Fold Belt (Kerr, 1977a). The area was part of the Franklin Miogeosyncline during early Paleozoic time, however, it was added to the Arctic Platform in Devonian time by pulses of differential vertical uplift of the underlying Boothia Horst (Table 4, from Kerr, 1977a). At least 14 MVT showings are found in a 100 by 200 km area east of the North Magnetic Pole.

Kerr (1977b) recognized four probable controls of mineralization:

(1) the host is the upper bioclastic part of the Ordovician Thumb Mountain Fm. (12 of 14, the other 2 are also in carbonate).

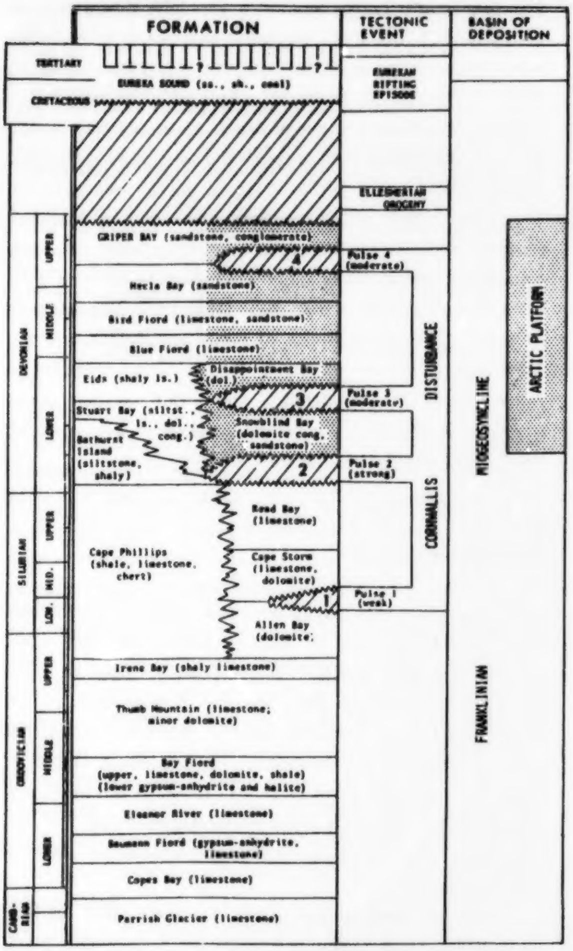
(2) the host rock is locally brecciated dolomite (14 of 14, sparry dolomite veining known as pseudobreccia is common).

(3) the showings lie within the bounds of the Cape Phillips shale basin and structurally higher than the shale (10 of 14, the Cape Phillip shales may be a source of the metals).

(4) the host is overlain unconformably by the Disappointment Bay Fm., (Pulse 3 in Table 4), (7 of 8, one is in the Disappointment Bay and 6 are unknown).

The sub Disappointment Bay unconformity is related to Early Devonian uplift on the basement Boothia Arch and is confined to the Cornwallis Fold Belt. Local karsting, dolomitization and mineralization must have taken place during this hiatus.

Table 4 Stratigraphy and tectonic events of the Cornwallis Lead-Zinc District (from Kerr, 1977b).


FORMATION
TECTONIC EVENT
BASIN OF DEPOSITION
TERTIARY
CRETACEOUS
EUREKA SOUND (ss., sh., coal)
EUREKAN RIFTING EPISODE
ELLESMERIAN OROGENY
DEVONIAN
UPPER
MIDDLE
LOWER
GRIPER BAY (sandstone, conglomerate)
4
Pulse 4 (moderate)
Hecla Bay (sandstone)
Bird Fiord (limestone, sandstone)
Blue Fiord (limestone)
Eids (shaly ls.)
Disappointment Bay (dol.)
3
Pulse 3 (moderate)
Stuart Bay (siltst., ls., dol., cong.)
Bathurst Island (siltstone, shaly)
Snowblind Bay (dolomite cong, sandstone)
2
Pulse 2 (strong)
DISTURBANCE
CORNWALLIS
MIOGEOSYNCLINE
ARCTIC PLATFORM
SILURIAN
UPPER
MID.
LOW.
Cape Phillips (shale, limestone, chert)
Read Bay (limestone)
Cape Storm (limestone, dolomite)
1
Pulse 1 (weak)
Allen Bay (dolomite)
ORDOVICIAN
UPPER
MIDDLE
LOWER
Irene Bay (shaly limestone)
Thumb Mountain (limestone; minor dolomite)
Bay Fiord (upper, limestone, dolomite, shale) (lower gypsum-anhydrite and halite)
Eleanor River (limestone)
Baumann Fiord (gypsum-anhydrite, limestone)
Copes Bay (limestone)
CAMBRIAN
Parrish Glacier (limestone)
FRANKLINIAN

Prospecting, soil geochemistry, gravity and IP surveys have all been used successfully to locate showings and drill targets

The Polaris Deposit. Cominco Ltd.'s Polaris mine on Little Cornwallis Island is the world's most northerly metal mine and will be its eleventh largest zinc-lead producer in terms of metal production. Pre-production reserves amounted to 23 million tonnes of 4.3% Pb and 14.1% Zn, using a cut-off of 10% combined and allowing 10% dilution at zero grade. The deposit is open at both ends and a considerable amount of mineralization below 10% combined is thought to exist.

The Polaris orebody is a north-trending lens with a thick eastern section called the Keel zone and a thinner conformable wing extending undip to the west called the Panhandle zone. The top of the ore lies from 60 to 150 m below the surface. The orebody has a maximum thickness of 120 m, a maximum width of 275 m, and a known length of 300 m.

Jowett (1975) studied the mineralization of the Polaris deposit and reported fluid inclusion temperatures in the range 50°C to 105°C, similar to temperatures for Pine Point. The ores are similar in other ways as well. Colloform sphalerite is the dominant sphalerite phase. It occurs as thin colour-banded botryoids and encrustations on the host rock. Less commonly, sphalerite forms brown crystals up to several centimetres across. Coarse galena cubes line vugs and are disseminated in sparry dolomite gangue. Marcasite coats and is coated by other sulphides. Petroliferous partings are common in the ore zone, but very little barite and no fluorite or native sulphur has been reported.

The ore zone is porous and contains an estimated 5% voids, which are filled with ice as the entire deposit is in permafrost.

The Eclipse Deposit. Near the center of eastern Little Cornwallis Island, it contains 1 million tonnes averaging in 13% Pb + Zn that could be mined using open pit methods. It would be an important deposit in any southern MVT district, but is almost insignificant when compared to the near-by Polaris deposit and development is unlikely for some time.

The Strathcona Sound District

The Strathcona Sound District is contained in a major 25 km wide northwesterly trending graben that extends across the Borden Peninsula of Northern Baffin Island (Figure 1). This graben contains a thick relatively flat lying sequence of Proterozoic sediments that have been folded and faulted into a series of smaller horsts and grabens. Indications of mineralization have been found along the entire 150 km strike length, but only the western third of the belt, south of Strathcona Sound, contains significant deposits and prospects.

The Society Cliffs Fm., which contains the MVT mineralization, is a medium brown to grey, laminated algal dolomite, which normally gives off a strong petroliferous odour. Solution collapse and crackle breccias are common.

Most of the sulphide bodies, including the Nanisivik deposit, were discovered as outcropping sulphides or gossan. Their subsurface extent was mapped and explored by means of electromagnetic surveys (Clayton and Thorpe, 1982). Vertical loop and VLF EM techniques have been the most widely used.

The Nanisivik Deposit. This MVT deposit is characterized by a high proportion of iron sulphide (pyrite and marcasite), high silver associated with the sphalerite and a Precambrian age of the ore and host rock as demonstrated by a 650-700 m.y. old gabbro dyke that cross cuts them (Jackson et al., 1978). In cross-section, the deposit is shaped like a flattened tube or lens 60 to 120 m wide and 2 to 20 m thick, known as the 'main' or 'upper lens'. Commonly a second, 'lower lens' of sulphide is present below the main lens and connected to it by a vertical keel. In cross-section it resembles an overturned H. In plan view it looks like a gently meandering river channel over its 3 km length.

Typical ore consists of euhedral to subhedral grains of sphalerite and galena with anhedral pyrite, sparry dolomite and ice as gangue. Sulphide ore is normally well bedded, commonly with cut and fill and onlap features. Massive pyrite and very coarse grained sulphide breccias are locally developed. Both pyrite and sphalerite stalactites are present but very rare. Olson (1977) reported wurtzite.

Long, horizontal fins of host rock dolomite (Figure 5) and related corrosion features are common in the mine workings of the main lens. Ford (1982) estimated at least 95% of the volume of the main ore cavity was created by ore fluids dissolving dolomite as sulphide was emplaced.

Hawker Creek Showings. At Hawker Creek, 23 miles southeast of the Nanisivik deposit, there are more MVT showings (Olson, 1977). The best showing, trench SH 25-1, comprises banded coarse grained sphalerite with minor galena, carbonate and abundant massive pyrite that has an average grade of approximately 15.4% zinc and 1.6% lead over a length of 50 feet. Mineralogy, texture, host rock and contact relationships are similar to Nanisivik; unfortunately detailed drilling failed to increase its size.

The Umanak-Clyde River District

Carbonate hosted lead-zinc is mined from marble of the Marmorlik Fm. at the Black Angel Mine in the Umanak area of Western Greenland (Fish, 1974 and 8 in Figure 1). While MVT deposits are normally thought to occur in unmetamorphosed carbonates, the Black Angel deposit may represent a 'well-done MVT'. It bears a closer resemblence to MVTs than other types of lead-zinc deposits and can be explored in much the same way as MVTs.

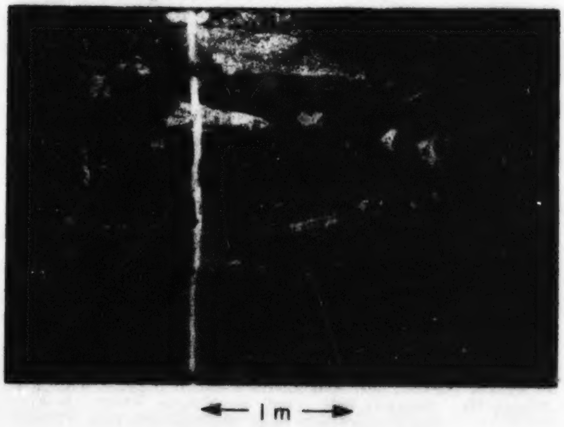
The Clyde River area (A in Figure 1) of Central Baffin Island has geology similar to that of the Umanak District and they may have been joined before sea-floor spreading formed Baffin Bay. At least one group has done reconnaissance exploration in the Clyde River area.

NON PRODUCING MVT DISTRICTS OF NORTHERN CANADA

Mackenzie Mountain Districts

The Mackenzie Mountain Fold Belt is in the Eastern Marginal Belt of the Northern Cordillera. This belt is a broad tectonic region consisting mainly of Upper Proterozoic to Devonian carbonates and clastics (Figure 6). Between 1972 and 1976 the area saw intense prospecting for MVT deposits. Upwards of 25,000 claims were staked and hundreds of showings located. Many of these were drilled and several significant deposits outlined. Rugged relief affords excellent exposure (Figure 7B) and permits simple prospecting by visual observation of mineralization and positive reaction with zinc spray (dithizone solution), but helicopters are required for transportation and resupply.

Initially, vuggy, orange-weathering dolomites of the Lower Cambrian Sekwi Formation were explored, but later work showed that the small, low to high grade showings in



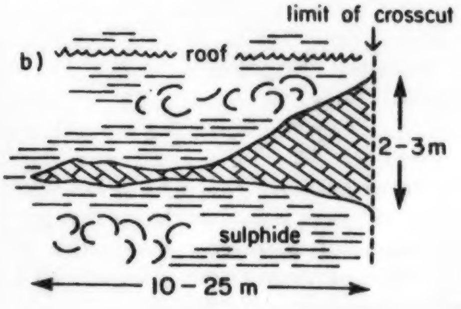


Figure 5 Fins of north dipping Society Cliffs dolomite showing solution-corrosion notches in horizontal sphalerite-pyrite-sparry dolomite mineralization, Nanisivik mine, (Sketch from Ford, 1981).

the Sekwi have no economic potential, whereas several important discoveries occur in other carbonate units. Some showings are related to the platform carbonate-basinal shale facies changes, while others occur some distance into the platform carbonates (Dawson, 1975; Brock, 1976 and Figure 6). Godwin et al., (1982) distinguish different ages and types of mineralization from lead isotope and trace element studies. Small, spectacular high-grade showings in breccia zones related to Laramide faulting are not MVT (C. Lord, personal communication, 1982).

Gayna River District. The Gayna River deposits are mainly associated with the margins of spectacular stromatolite reefs that grew within shallow-water carbonates, of the Host Unit of the Little Dal Group of Helikian age (Hewton, 1982; Hardy, 1979). The Host Unit carbonates are underlain by shale and overlain by a silty dolomite containing a thick gypsum unit. The reefs, which may reach lengths of 6 km and heights of 500 m (Figure 7), are believed to have developed on basement highs along a possible basin-platform hinge-zone related to the Mackenzie Arch (Figure 6). The mineralized region is a large "box" anticline cut by numerous normal faults (Figures 2 and 19 of Hewton, 1982). A sub Upper Cambrian unconformity, just above the gypsum, is thought to have influenced karsting and brecciation.

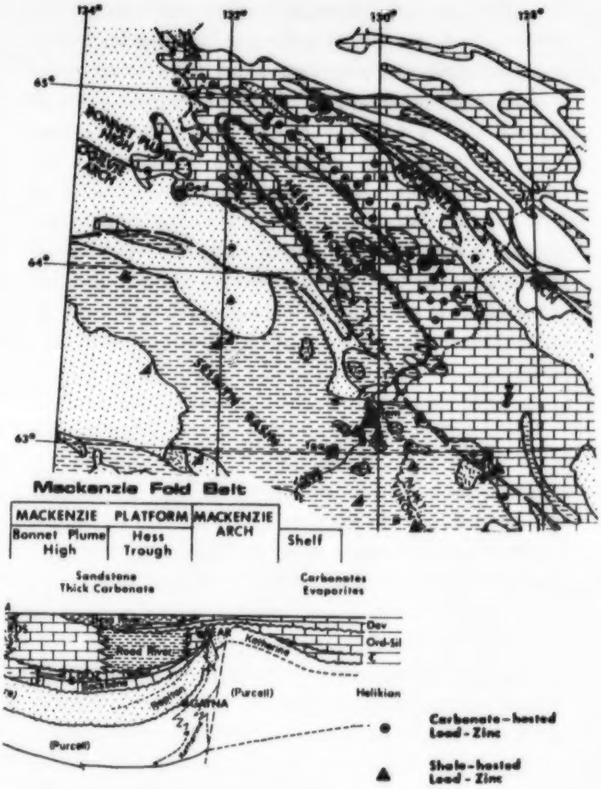


Figure 6 Map of Geology and Zinc-Lead Deposits Mackenzie Fold Belt (from Brock, 1976).

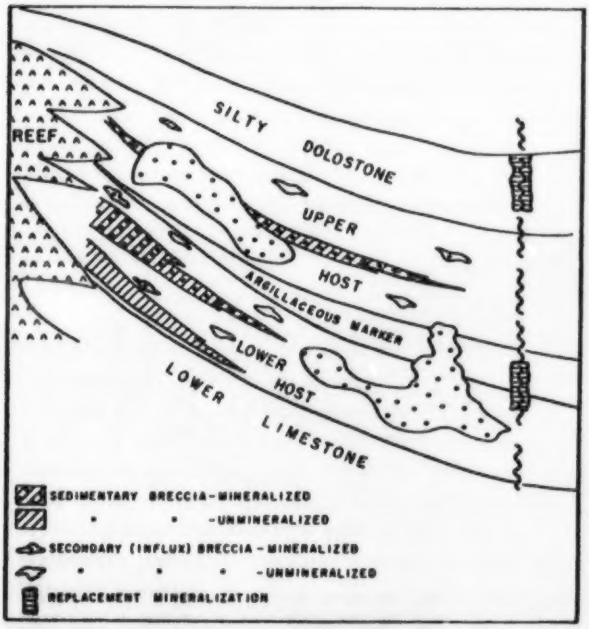


Figure 7A Schematic cross section Gayna River with reef flank and types of zinc-lead mineralization (from Hewton, 1982).

Figure 7B Stromatolitic reef at Gayna River, N.W.T. Note carbonate beds draping over reef. Photo by Chris Lord.

Hardy (1979) made a detailed and comprehensive study of the breccias, classifying them into two types on the basis of matrix composition. Sedimentary breccias are mainly reef talus and slump breccias (Figure 7A). They may contain low grade mineralization, less than 3% Pb + Zn. Secondary breccias, formed by solution-collapse and distinguished by white sparry carbonate, may grade up to 20% Pb + Zn. These better grade zones contain abundant sparry carbonate and sphalerite mineralization with a wide variety of colors and replacement textures. Diamond drilling has shown some of these mineralized breccia zones to be comparable in size and grade to ore bodies in the Pine Point District, but they are not good enough to justify economic development in this remote area. Geologically-indicated reserves at Gayna are estimated to be in excess of 50 million tonnes of greater than 5% combined lead-zinc (Hewton, 1982). Small high-grade replacement deposits occur along linear features throughout the section (Figure 7A), but have no economic potential.

Bonnet Plume District. In June 1973, mineralized dolostone rubble and very high zinc and lead stream sediment values were discovered in several tributaries of Goz Creek in a remote part of the eastern Yukon near the headwaters of the Bonnet Plume River. At Goz Creek, more than 2,000 feet of shallow-water carbonates were deposited near the southern extremity of the Bonnet Plume High, an active structural feature that formed part of the shelf between the Selwyn Basin and the Hess Trough shale basins during Late Precambrian and Early Cambrian time (Figure 6). Low displacement faults were periodically activated to become loci of paleokarst-breccia systems and secondary fractures, which were later mineralized with sphalerite, silica and sparry dolomite.

A potential of 10.9 million tonnes of 8% zinc with minor cadmium and silver has been outlined by 7,000 m of drilling at the Goz Creek prospect of Barrier Reef Resources Ltd. in Uppermost Precambrian, middle member of the Backbone Ranges Fm. (Fritz, 1982). This deposit has spectacular high-grade outcrops and large amounts of smithsonite and silica not common to other MVT districts of Northern Canada. Three modes of mineralization occur in the main HAB zone: (1) Northwest trending siliceous breccia zones are heavily mineralized with red, brown, yellow and light green sphalerite (5 to 30% Zn), plus minor amounts of galena, pyrite and boulangerite (Reeve, 1977); (2) Low grade (2% Zn) manto mineralization, consisting of fracture fillings, disseminations and vug fillings, occurs in crackle breccias along selected beds surrounding mineralized collapse breccia; (3) Fine bedded sphalerite and silica (8% Zn) occurs in and adjacent to the HAB breccia zone. Smithsonite zones on the upper flanks of the HAB breccia zone (above 1,500 m elvation) extend to depths of 80 m and are thought to be remnants of pre-glacial chemical weathering that are preserved on non glaciated mountain peaks or nunataks.

Godlin Lakes District. This area, located 300 km northeast of Ross River along the Canol Road, was the site of the first discoveries in the Mackenzie Mountains in 1972. The most significant is Welcome North Ltd.'s BEAR-TWIT deposit, 40 km northwest of the Godlin Lakes on the Twitya River. Here 7.2 to 9 million tonnes of stratabound mineralization (8% Pb-Zn and 16 ppm silver) occurs in brecciated, possibly karsted, dolomites of the Wittaker Fm., near a major shale-carbonate facies change (Figure 6).

Numerous lead-zinc showings occur in Lower Cambrian to Middle Devonian shelf carbonates of the Godlin Lakes area.

Northern Rocky Mountains

Promising MVT deposits have been found in platform carbonates of the Muncho-McConnell, Stone, Pine Point-Sulphur Point and Slave Point Formations in the Rocky Mountains of Northeastern British Columbia (Figure 1), (Macqueen and Thompson, 1978). To the west and north, the carbonates give way to basinal shales of the Besa River Fm. that have been suggested as the source of the metals and pyrobitumem in the deposits.

Robb Lake Deposit. This deposit occurs within a brecciated Silurian-Devonian dolostone succession of transgressive progradational sabka rhythmites (Manns 1982 a, b). Manns identified a relative sag in groups of rhythmites from the brecciated areas that demonstrate the origin of collapse-breccias. Manto-like breccias may have formed by hydraulic fracturing by formational fluids released during tilting caused by differential compaction of an underlying shale-carbonate facies front.

Initial exploration interest in the Robb Lake area is rumored to have been sparked by projecting the MacDonald-Hay River fault system that passes through the Pine Point District, southwesterly to an area of abundant outcrop (Figure 1 and Figures 4 & 6 of Sikabonyi and Rodgers, 1959). Some 5.5 million tonnes of 7.3% Pb +Zn in breccias has been reported for Robb Lake.

OTHER AREAS

Potential Lead-Zinc Districts

These are areas where considerable time and effort have been spent exploring for MVT deposits and a number of small showings are known.

Hay West. The Hay West area (B in Figure 1) includes the area north of Hay River and contains the southwesterly extension of the Pine Point or Keg River barrier complex and the Presquilized hinge zone at depths of 500 to 650 m. In 1979, Cominco Ltd. and partners staked more than 2,000 square kilometers and expended several million dollars drilling and conducting seismic and IP surveys. Gulf Minerals Ltd., did similar work south of the Tathlina Fault from 1976 to 1978.

Windy Point. Lead-zinc showings and oil seeps have been known in Presquilized patch reefs in the Windy Point area (C of Figure 1) for many years and several thousand metres were drilled in the 1950s (Norris, 1965). Between 1977 and 1980 Cominco Ltd. staked two large claim groups, did geochemical and IP surveys and drilled several exploration holes in this area.

Wrigley - South Mackenzie Plain. Cominco, Giant Yellowknife Mines and Union Oil explored Middle Devonian carbonates in this area (D, Figure 1) during the 1970s, Paleokarst features such as sink holes and solution collapse breccias are common throughout the area but are not mineralized. Sphalerite, galena and sparry carbonate are associated with dolomitized, oxidized and silicified zones in Laramide fault breccias in Middle Devonian Nahanni Fm. limestones (Heal, 1976).

Areas of Favorable Geology

These are areas that have geological potential for MVT deposits, and contain basinal or platform carbonates, but for any number of reasons have seen little or no exploration.

Northern Interior Plains: The Horton Plain (E), the Anderson Plain (F) and the Collville Hills (CL). This area contains a number of known oil and gas seeps, a thick Paleozoic platformal sequence with important evaporite and solution collapse breccias and numerous unconformities (Gilbert, 1973). Important tectonic lineaments are suggested by rivers and lake shorelines. Poor accessibility and sparse outcrop, preclude cost efficient exploration for MVTs but spin off from an expected increase in oil and gas exploration in this area may lead to the discovery of lead-zinc.

The Franklin Miogeosyncline (G and H). The Franklin Miogeosyncline contains a long belt of Thumb Mountain Fm., the principle host rock in the Cornwallis Lead-Zinc District. However, the sub-Disappointment Bay Fm.unconformity and associated karsting, dolomitization and mineralization are absent beyond the Cornwallis Fold Belt (Kerr, 1977a). Nevertheless a number of exploration programs for MVTs have taken place in this area and a small deposit of MVT mineralization was discovered on Judge Daly Promentory near the northeastern corner of Ellesmere Island by oil geologists in 1973. Pale colored sphalerite with minor galena occurs in algal dolomite of the Copes Bay Fm.

Brodeur Peninsula (I) and Victoria and Banks Islands (J). The Arctic Platform contains vast areas of platformal carbonate, but aside from some interesting solution breccias on Brodeur Peninsula, little is known about their MVT potential. The same can be said for two poorly exposed Paleozoic cratonic basins, the Foxe Basin (K) and Northern Hudson Bay Basin (L) and two areas of Proterozoic platform carbonates in the Athapuscow Aulocogen (M) and zone 2 of the Wop-May Orogen (N).

DISCUSSION

Since 1970, more than 50 million dollars has been spent on exploration for Mississippi Valley type lead zinc mineralization in Northern Canada. This expenditure has financed efforts that resulted in the discovery of greater than 100 million tonnes of ore and geological reserves. It has lead to the discovery of several new MVT districts and significant expansion of others. It has lead directly and indirectly to additional large capital expenditures related to the innovative development of two new mines in the Arctic Islands and expansion and modernization of facilities at Pine Point.

It is accurate to describe production of lead and zinc from Mississippi Valley type deposits as the mainstay of mining in Northern Canada. Two northern communities owe their existence to MVT deposits. The future of exploration and mining for lead, zinc and other minerals in Northern Canada is uncertain, but with the right economic climate, exploration groups will continue to find and possibly even explain MVTs.

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Contributions to the geology of the Northwest Territories
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GEOLOGY OF THE THOR LAKE BERYLLIUM DEPOSITS: AN UPDATE

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INTRODUCTION

The Thor Lake beryllium-tantalum-niobium-zirconium-rare-earth deposits are situated approximately 95 kilometres southeast of Yellowknife, NWT, and are centred 5 kilometres north of the Hearne Channel on Great Slave Lake (Fig. 1). In this area, the deposits form an apparently integral part of the much larger Aphebian Blatchford Lake Alkaline Complex and may represent the late stage, highly fractionated magmatic and metasomatic products of the complex.

First documented by early Geological Survey of Canada mapping, the Blatchford Lake Complex was considered to be of Archean age (Stockwell, 1932). Subsequent work (Davidson, 1972, 1978; Hoffman and others, 1977) has shown the complex to be of uncertain age but probably closely related to the development of the aulacogen which occupied the East Arm of Great Slave Lake.

Interest in the Thor Lake area was first engendered by reports of radioactivity in a number of "showings" in syenitic rocks near Thor Lake. The ground was subsequently staked in 1970, but allowed to lapse because of a lack of interest in the showings. In 1976, the ground was restaked by Highwood Resources.

In 1977, Highwood undertook a short drilling program on the so-called 'S'-zone, while conducting a program of mapping and trenching on the adjacent 'T'-zone. Diamond-drilling in 1978 on the T-zone subsequently established a reserve therein of approximately 1.2 million tonnes at a grade of 0.55% Nb_2O_5, with an additional inferred tonnage of 6-7 million tonnes.

In 1979, test drilling of the 'Lake'-zone confirmed the existence of similar deposits under Thor Lake and in 1980 further drilling of this zone resulted in the outlining of a deposit of the order of 65 million tonnes grading 0.03% Ta, 0.40% Nb, 3.5% Zr, and 1.7% combined rare-earths.

During the summer of 1983, the R, S, and T-zones were resampled to test for occurrences of beryllium; the beryllium-bearing mineral phenacite having been identified during Geological Survey of Canada investigations (Davidson, 1978). The results of this work warranted a subsequent berylometer survey of the T-zone and in turn diamond-drilling. By March of 1984 a reserve of 1.77 million tonnes at a grade of 0.75% BeO had been blocked out.

Presently, the beryllium deposits are being subject to pre-feasibility study for production purposes, and work is ongoing to determine values of possible co-product mineralization. In addition, geological investigations are ongoing in the Lake-zone area, and hence remarks and geologic descriptions which follow will largely be confined to the R, S, and T-zones.

GENERAL GEOLOGY OF THE THOR LAKE AREA

The geology of the Thor Lake area, and the Blatchford Lake complex is shown in Figure 2 after Davidson (1978). For a detailed description of the complex, the reader is referred to Davidson (1972; 1978), for a petrochemical description of the complex to Davidson (1981; 1982), and for a description of the regional setting the reader is referred to the geologic compilation of P.F. Hoffman which accompanies Davidson (1981).

In general, it is seen that the Blatchford Lake Complex consists of a consanguineous sequence of gabbros, anorthosites, syenites, quartz syenite, granite, and related alteration products; all of which intrude metasedimentary and granitic rocks of Archean age. Within the confines of Thor Lake and the R, S, and T-zones proper, syenitic rock types dominate and have collectively been assigned the term Thor Lake Syenite by Davidson. These include:

a) "coarse to medium-grained, dark green, rusty-weathering fayalite-pyroxene syenite, locally containing enigmatite and hornblende

b) coarse-grained hornblende syenite

c) inequigranular hornblende syenite characterized by very coarse, highly poikilitic hornblende

d) subporphyritic hornblende syenite

e) medium-grained hornblende syenite with aligned hornblende crystals."

The fayalite-pyroxene syenite (a, above) is locally termed "Rim Syenite" because of its annular form around much of the Thor Lake Syenite and its prominent higher physiographic relief.

Locally, an additional phase of syenite is found which is seen to consist of subhorizontal pods or sheets of syenite pegmatite. These rocks consist of pegmatitic euhedra of amphibole and/or pyroxene and feldspars of unknown composition, set in matrices of fine-grained aplite to coarse-grained albite (?).

GEOLOGY OF THE THOR LAKE T-ZONE

The oldest rock type noted in the T-zone is a diabase which occurs as inclusions in syenite at several locales. This rock, characteristically dark brown or black weathering, is fine to medium grained and marked by inclusions of lithic material, blebs of magnetite and/or quartz, and carries phenocrysts or xenocrysts of perthitic composition. In turn, the rocks of the Thor Lake area are all seen to be cut by younger felsite and diabase (Mackenzie) dykes.

A north-south longitudinal geologic section and accompanying index map of the T-zone are shown in Figure 3. The section displays five lithologic units, all of which are mantled by syenite. The system of nomenclature assigning various of the rock types to zones has been developed based on an apparent orderly distribution of mineral assemblages and as a matter of convenience. Descriptions follow:

Syenite: Syenite is largely as described by Davidson (1978) and is a buff to rusty-brown weathering, massive to locally schistose, coarse-

EAST ARM, GREAT SLAVE LAKE		BLACHFORD LAKE AREA	MAP-UNITS
MACKENZIE DIABASE DYKES	=	MACKENZIE DIABASE DYKES	–
BASIC SILLS, CHRISTIE BAY		NOT PRESENT	
ET-THEN GROUP		NOT PRESENT	
DIORITE, MONZONITE LACCOLITHS	=	DIORITE GRANODIORITE	9a,b
GREAT SLAVE SUPERGROUP		NOT PRESENT	
EAST-NORTHEAST DIABASE DYKES	=	EAST-NORTHEAST DIABASE DYKES	–
'EASTER ISLAND DYKE'	=	BLACHFORD LAKE INTRUSIVE SUITE	1-8
WILSON ISLAND GROUP		NOT PRESENT	
ARCHEAN METAMORPHIC COMPLEX	=	(TWO-MICA GRANITE (BIOTITE GRANODIORITE (YELLOWKNIFE SUPERGROUP	Agr Agd As

UNIT	ROCK UNITS
7,8	ALTERATION, VEINING AND MINERALIZATION
–	TRACHYTE DYKES
6	THOR LAKE SYENITE
5	GRACE LAKE GRANITE
4	MAD LAKE GRANITE
–	LEUCOCRATIC PERTHITE GRANITE
3	HEARNE CHANNEL GRANITE
2a,b	WHITEMAN LAKE QUARTZ
1a,b	CARIBOU LAKE GABBRO
–	ANORTHOSITE ANORTHOSITIC GABBRO

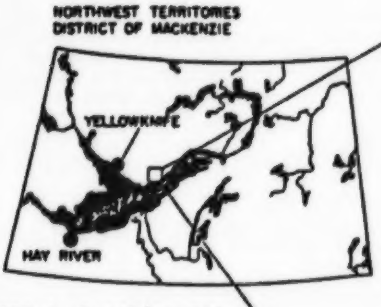

FIGURE 1: Location map of the Thor Lake Area.

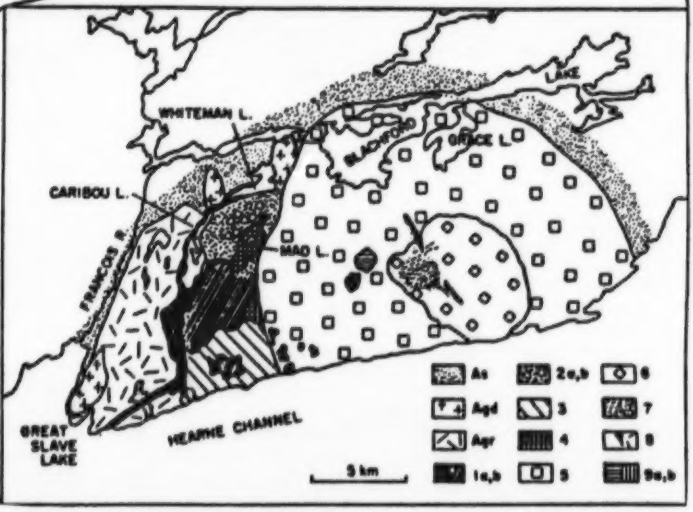

FIGURE 2: Generalized geology of the Blatchford Lake area after Davidson (1978).

grained rock consisting chiefly of plagioclase (in part perthitic) euhedra set in a matrix of hornblende (riebeckite), magnetite, and/or minor amounts of quartz. Zircon, strongly zoned, is present as a common accessory. Pegmatitic patches or segregates as described above, are present locally.

Granite : Within the confines of mapping, the term granite is used to describe a medium to coarse-grained, massive, buff to pink weathering rock which crops out extensively in the north end of the T-zone. Mineralogically, the granite is seen to consist predominantly of perthite, quartz, and riebeckite with accessory magnetite, zircon, monazite(?), carbonate, fluorite, and phenacite(?).

Contact relations between granite and adjacent syenite are obscure; to the west the granite appears to phase into syenite with an abrupt disappearance of quartz, and to the east appears to dip shallowly eastward under the Rim Syenite.

Wall zone : The term Wall zone is used to describe a massive, fine to coarse-grained (locally pegmatitic) feldspathic zone developed around more severely altered rocks in cores of the R, S, and T-zones. The rock is characteristically light pink to brownish-red weathering and consists largely of albite and acicular radiating cleavelandite(?). The quartz content of the rock is varied with much of the quartz appearing to be of a secondary nature in the form of blebs or veinlets. Fluorite is common, as are fine-grained sulphides, magnetite, carbonate, columbite, phenacite, and several unidentified REE-bearing species.

In a number of outcrops in the north end of the T-zone, brecciation of wall-zone rocks is common and large (less than 20 cm) angular blocks of albitite appear to be floating in a matrix of massive quartz.

Lower Intermediate zone : The term Lower Intermediate zone is used to describe rocks occuring predominantly in the core of, or as keels in, the S and T-zones. These rocks are massive, coarse-grained, and black to dark weathering as a result of extensive manganese staining. In composition they consist principally of quartz, plagioclase, amphibole,

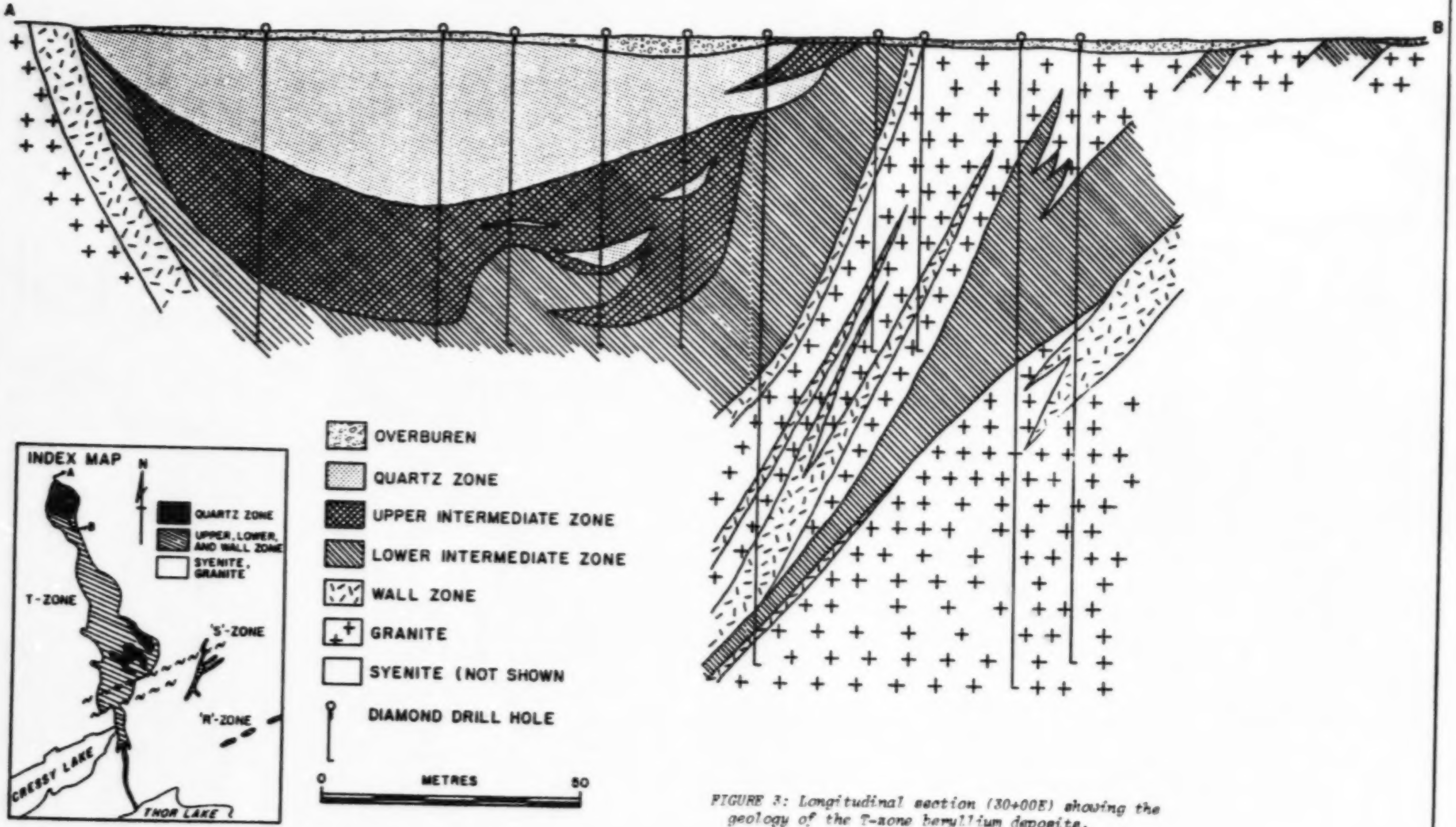

FIGURE 3: Longitudinal section (30+00E) showing the geology of the T-zone beryllium deposits.

various micas, chlorite, carbonate, and magnetite. Mica types identified include biotite, muscovite, and lepidolite. Accessory minerals include fluorite, zircon, sulphides (including sphalerite and galena), phenacite(?), columbite, and several unidentified REE-bearing species.

Textural similarities and preserved relicts of granite in the north end, and syenite in the south end of the T-zone, suggest that these rocks may have formed protoliths to the assemblages that now exist in the Lower Intermediate zone.

Upper Intermediate zone : Rock types of the Upper Intermediate zone are confined exclusively to the T-zone. In outcrop, and as shown in Figure 3, these rocks are disposed above, or intercalated with, rocks of the Lower Intermediate zone or are in contact with the overlying Quartz zone. In outcrop these rocks are seen to be massive, coarse grained, and unweathered in appearance. In composition, rocks of the Upper Intermediate zone are characterized by euhedra of quartz, muscovite, albite (cleavelandite?), acmite, and optically continuous phenacite. Chlorite, fluorite, carbonates, magnetite, sulphides, and unidentified REE-bearing species are present in accessory amounts.

In several places at the north end of the T-zone, the rocks of the Upper Intermediate zone display megascopic textures similar in appearance to the brecciated Wall zone rocks described above. In these areas, breccia fragments, like those of the Wall zone, are almost exclusively replaced and the rock is now characterized by dark-weathering schlieren.

Quartz zone : In the T-zone area, rocks of the Quartz zone lie in contact with all rock types of the Wall zone, Lower Intermediate zone, and Upper Intermediate zone. In the foremost case, brecciation is noted, and in the latter cases contacts are generally intercalated but sharp. In sections other than that shown in Figure 3, rocks assigned to the Quartz zone are also found discontinuously disposed in the Lower and Upper Intermediate zones.

In composition, this zone is composed predominantly of quartz. Locally, assemblages are noted which carry albite, muscovite, carbonate, fluorite, phenacite, and several unidentified REE-bearing species. Fluorite is a common accessory, forming large (less than 8 cm) zoned crystals of dodecahedral habit ranging from colorless to green or purple.

Vugs and druse-filled cavities are common with matrix quartz crystals being coated with carbonates, sulphides, and as yet unidentified red and/or green-coloured minerals.

STRUCTURAL GEOLOGY

Geological mapping in the Thor Lake area presently indicates that most of the syenitic and granitic rocks are horizontally disposed or dip shallowly to the east and may pass under the Rim Syenite. Superimposed on these rocks are the alteration assemblages of the T-zone, described above, which trend northwesterly from the north shore of Thor Lake.

In plan view the T-zone appears as a prominent linear feature varying in width up to several hundred metres at the north and south ends (see index map, Figure 3). In cross-section the T-zone appears widest at the surface and narrows with depth exhibiting a keel-like form. The alteration assemblages are distributed in a concentric layer-like orientation suggesting an orderly zoning pattern. In longitudinal section the T-zone appears as in Figure 3. To date, diamond drilling has not disclosed the full extent of the alteration assemblages.

Faulting is in evidence in the T-zone in a number of locales where at least the eastern boundary of the zone is formed by northwest-trending, essentially vertical shears.

At its southern end, the T-zone is terminated by faulting (Fig. 3). In this area two faults are prominent, trending ENE and dipping vertically. The net effect of apparent vertical movement on these faults is one of progressive uplifting of the T-zone keel southward with an attendant, apparent thinning of the zone at present levels of exhumation. In the R and S-zones ENE-trending faults are also in evidence. In the R-zone, the faulting appears to localize alteration assemblages, and in the S-zone faulting transects and offsets the alteration zone.

ECONOMIC GEOLOGY

The occurence of beryllium at Thor Lake was first mentioned by Davidson (1978). Phenacite was identified as one of a number of accessory minerals. In 1983, as part of a lithogeochemical orientation survey, samples were collected by Highwood from the R, S, and T-zones specifically for beryllium analysis. Some of the samples contained in excess of 2% BeO. A berylometer survey initiated just prior to freeze-up resulted in the identification of two target areas for diamond drilling.

Surface sampling and berylometer survey work has established that beryllium occurs in various proportions throughout all of the assemblages in the T-zone. This distribution of beryllium mineralization is shown in Figure 4 which represents the same longitudinal section as in Figure 3 minus the geology. The presence of beryllium in the form of phenacite (Be_2SiO_4) in the quartz-rich assemblages poses an ongoing problem in that phenacite displays all the megascopic properties of quartz and renders futile all attempts to identify the mineral in drill core or samples. Extensive use of the berylometer has thus resulted in considerable savings in analytical costs.

In thin section, phenacite is similar to quartz, excepting for higher relief and a slight yellow birefringence suggestive of quartz in a thicker section. The phenacite is optically continuous, forming mantles on quartz or forming large aggregrates (less than 5 mm) intimately intergrown with the quartz.

At present, research is being directed towards at least six differing mineral species which display enrichment in the rare-earth elements. Additionally, work is ongoing to define distributions of columbite ($4(Fe,Mn)(Nb,Ta)_2O_6$) and the element gallium, which has been reported in analytical work but as yet has not been identified in mineral form.

SUMMARY

Geological investigations of the beryllium-bearing rocks at Thor Lake have resulted in the definition of a number of unusual alteration assemblages which appear to be products of meta-

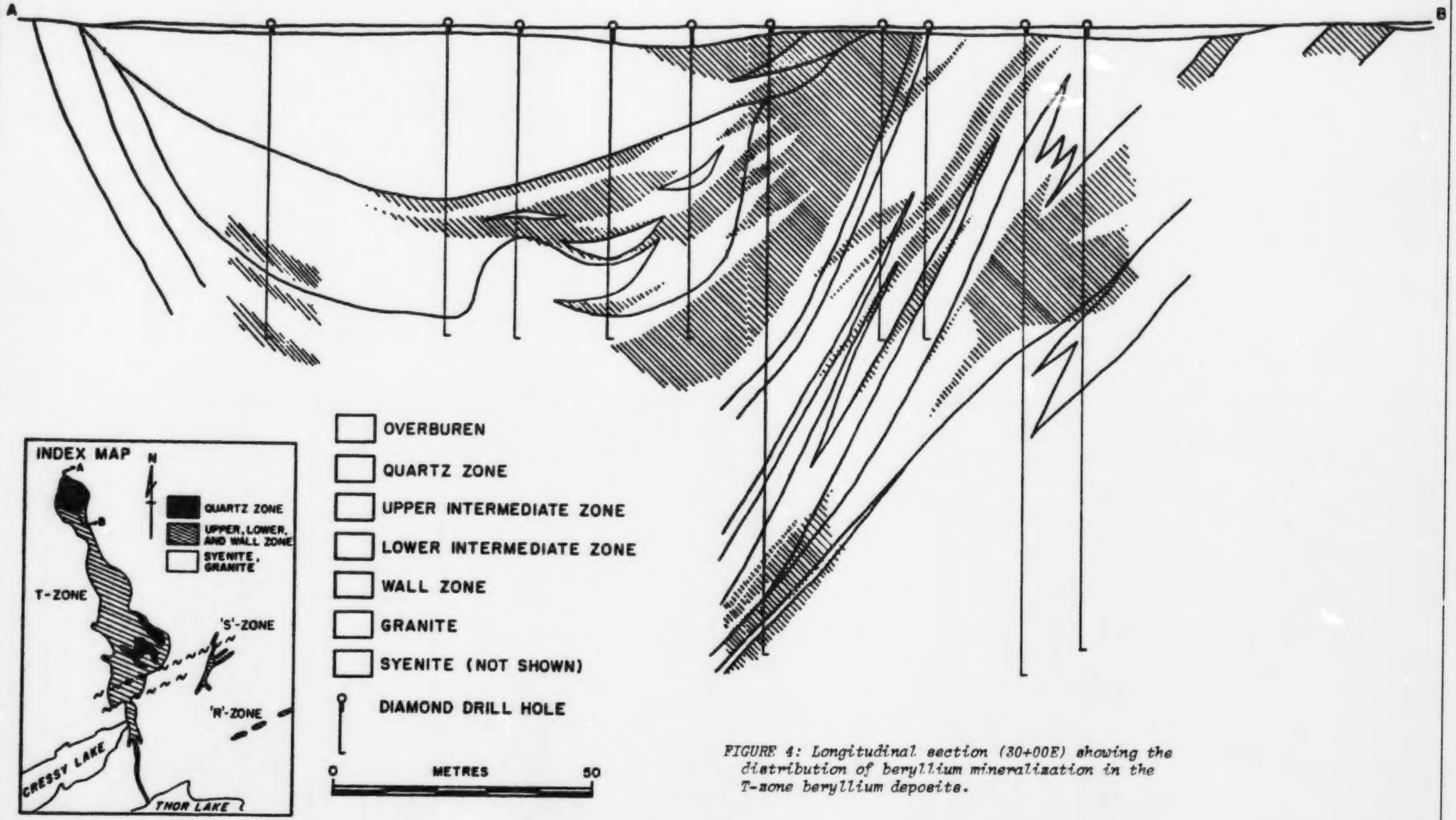

FIGURE 4: Longitudinal section (30+00E) showing the distribution of beryllium mineralization in the T-zone beryllium deposits.

somatic replacement of earlier-formed syenitic and granitic types. These assemblages, now modified by faulting, appear to have a concentric zoning pattern in their distribution and also appear to converge with depth into a keel-like zone.

Beryllium mineralization is widespread in all of the rock types in the area, excepting in syenite. Its localization is not understood, suffice to say that it appears to be intimately related to quartz in the alteration assemblages. Quartz is seen to brecciate Wall-zone rocks, and in turn this suggests that the beryllium-mineralizing event occured late in the sequence of development.

Areas of future research interest should probably include petrochemical definition of the various rock types to determine the nature of the metasomatic exchange noted. Also, some attempt should be made to fingerprint the original source of the mineralization; i.e., is it related to the Thor Lake Syenite or the Grace Lake Granite? Did the emplacement of either of the aforementioned intrusions remobilize the metals one from the other?

ACKNOWLEDGEMENTS

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GOLD DEPOSITS OF NWT

Classes, Styles, Genesis, Exploration Methods and Success Probabilities

W.A. Padgham
NAP, Geology, Yellowknife

INTRODUCTION

Gold mining, which began in the Yellowknife Bay area in 1935, has gone on continuously since 1938 at mines in Yellowknife and has been a major component of the NWT mineral industry. By the end of 1983, $850 million of gold had come from NWT mines, 17% of the approximately $5 billion of mineral products of 53 years of NWT mineral production. With three new mines recently on stream and three on the horizon, gold should maintain its position in the long term.

To assist prospecting for new showings and to put the possibilities of the 500 or so already discovered but as yet unmined showings in perspective, a number of tables have been prepared.

Table I, an updated version of a table published in the 1979 Gold Workshop Volume (Padgham, 1981), describes the various types of gold properties (mines, deposits and showings) in the NWT. Table II is from the same paper and gives data to 1983 on gold production. It is useful in assessing the probable profitability of the various types of deposits.

Table III was also originally done in 1979 when data were available for about 300 showings. Exploration since the freeing of the gold price in the early 1970s has brought to light 200 additional showings that are incorporated into the new table. Many of these showings were discovered in the 1960's or earlier, but inadequately documented. Others were found more recently during concerted exploration of nearby showings. These include some blind showings discovered by drilling.

Gold Production 1935-1983

Gold has been produced from the following types of deposits in the NWT (Table I):

(1) Shear zones in volcanics
(2) Quartz veins at sedimentary-volcanic contacts
(3) Quartz veins in turbidite-sediments
(4) Iron-formation and amphibolitic iron-formation deposits
(5) Paleo-placers (Fox deposit, Outpost Islands)
(6) Quaternary placers.

Until 1982 approximately 88% of all gold production in the NWT was from the Giant and Con-Campbell shear-zone systems (and associated quartz veins) at Yellowknife. Quartz veins in volcanics and sediments adjacent to volcanic-sediment contacts provided most of the rest of the gold (10% of the total), mainly from production at the Tundra and Discovery Mines. Gold has also been produced from at least 12 quartz-lode deposits in the turbidite sediments of the Yellowknife Supracrustal Basin. These are the most 'abundant' in terms of individual mines or number of deposits that have been mined, but production has been a trivial 1% of the total, one order of magnitude less than production from sedimentary-volcanic contact deposits and two orders less than production from shear zone deposits.

Production from Quaternary placers along the Liard River and some of its tributaries has been negligible. Production from the Fox Mine, which is on one of the Outpost Islands, has only been about 300,000 grams, but the unusual nature of the deposit and the continuity of the mineralized zone is of considerable interest.

Two of the NWT's newest and most promising mines, Cullaton Lake (B-Zone) and Lupin, are expected to produce more than half of the NWT's annual gold output in 1984. Potential for further mineable deposits of these two remarkably similar types, which are hosted in sedimentary iron-formation, has excited widespread exploration in a zone extending north and south from Cullaton Lake and in a broad swath across the central Slave Province.

Cullaton Lake Mines proposes to add a new type of deposit to the ranks of NWT producers. The Shear Lake deposit is in pyrite-bearing shear zones in Aphebian Hurwitz Group orthoquartzite overlying the Archean Henik Group greywacke/volcanic assemblage, which contains the sulphide iron-formation beds hosting Cullaton's B-Zone gold deposit. Gold may have been mobilized from parts of the Henik Group and deposited in the shear zones.

Terra Mines hopes to prove sufficient tonnage by 1984 at their Bullmoose Lake quartz-vein-in-turbidite deposit to warrant production at 300 tpd.

Canuc Resources has had some success in 'drill-proving' potentially mineable-grade material in the quartz veins that are hosted by the Anialik River Granite Gneiss, which represents yet another type (or sub-type) of gold deposit that may come on stream in a few years.

OVERVIEW OF SOME DEPOSIT TYPES

This brief review of some deposit types begins with the youngest and least productive deposits (with the least potential based on past performance) to those with the greatest potential and probability for success.

Cordilleran Deposits

Magmatic-hydrothermal deposits have been recognized only along the hinge between the Selwyn shale basin and the Mackenzie carbonate platform. They are low-grade, disseminated deposits formed during the intrusion of Cretaceous plutons. As there are at least 25 such intrusions within, partly within, or so close to the NWT border that their metamorphic effects are probably seen in rocks on the NWT side, there is considerable area for prospecting.

At this stage in the search, stream sediment geochemistry may be a useful tool to decide which areas are most favourable. Rock and soil geochemistry may be the only effective way to explore for deposits, and extensive drilling and probably bulk sampling would be required to test the profitability of any deposits found. IP surveys may be effective in areas with sufficient sulphides, but at present the potential of this type of deposit is essentially unknown. Gold distribution in areas explored in detail has proved to be highly erratic.

Young placers are found only in the Cordilleran Province of NWT. Elsewhere, streams are inappropriate for such deposits to develop. In all reported

TABLE I: TYPES OF NORTHWEST TERRITORIES GOLD DEPOSITS

TYPE	EXAMPLES	GENESIS	DESCRIPTION
1. Gold in quartz-carbonate-sericite shear zones	Campbell, Giant and Con Shear Systems	Epigenetic, hydrothermal	Large quartz-rich ore lenses with various sulphides, arsenides and sulphosalts within extensive sheared alteration zones cutting basaltic flows. Gold content relatively evenly distributed.
2. Gold in Quartz veins			
(a) in volcanic rock	Rycon, Negus	Epigenetic, hydrothermal	Quartz veins in shears but without extensive chlorite-sericite-carbonate.
(b) at or near volcanic-sediment contact	Tundra, Discovery Salmita	Epigenetic, hydrothermal	Narrow but consistently mineralized, small tonnage.
(c) in greywacke-turbidites	Thompson-Lundmark, Ruth, Old Parr, TA Group, Camlaren, Ptarmigan	Epigenetic, hydrothermal related to metamorphism	Highly irregular in width and erratically mineralized, few sulphides. Commonly controlled by folds and cleavage. May resemble 'saddle reef' deposits.
(d) in granitoid plutonic rocks	Arcadia property	Epigenetic, hydrothermal	Veins as much as 12 m wide and 100's of metres long. Grades low but relatively consistent.
(e) in quartz veins in dykes and sills	Hydra deposit (Colmac dyke)	Epigenetic, hydrothermal	Gold and minor sulphides in quartz veins and stringers cutting intrusive igneous rocks. Gold probably derived from same source as rock.
(f) in quartz stockworks	MOS Claims (in volcanics) MAG Claims (in greywacke)	Metamorphic mobilization of gold and quartz	Gold and minor sulphides disseminated in quartz veinlets, mainly parallel to bedding. Low but consistent gold grades across 10 to 15 m.
3. Gold in sedimentary rocks, mainly in iron-formation	Cullaton Lake, Contwoyto Lake, gold in graphitic slates	Syngenetic with mobilization and concentration during metamorphism	Gold with iron sulphides and arsenides and iron minerals disseminated in lean iron-formations and amphibolite of sedimentary origin.
4. Gold with sulphide deposits			
(a) Volcanogenic massive sulphide	Izok Lake, High Lake, Hackett River	Volcanogenic-hydrothermal (exhalative)	Generally low gold values disseminated throughout the mineralized zones.
(b) Disseminated sulphides & scheelite	Outpost Island	Hydrothermal ? Paleoplacer ?	Gold is associated with disseminated sulphide, tungsten and tin minerals in sheared and silicified zones in metasediments.
5. Gold disseminated in Cretaceous intrusions		Magmatic-hydrothermal	Very fine-grained (not macroscopically visible) gold with disseminated base-metal sulphides and tungsten minerals. May be erratic.
6. Placers		sedimentary	
(a) Aphebian	Hurwitz Group		Gold in pyritic conglomerates.
(b) Quaternary	Liard River bars		Very fine-grained flour gold in black sand layers. Replenished during high water stages.

TABLE II: GOLD PRODUCTION NORTHWEST TERRITORIES (TO END 1983)

PROPERTY	TYPE	PRODUCTION PERIOD	TONNES ORE MILLED	Kg PRODUCED	REFERENCE
GIANT (Lolar and Supercrest)	Quartz carb. shear zones	1948-83	10,782,386	175,296	CMH*. W.M.* & Giant Annual Reports
Con & Rycon	Quartz veins in shear zone & quartz carb. shear zones	1938-83	5,958,600	106,226	N.M.*, MNI*, CMH and Cominco Annual Reports
Discovery	Quartz vein in turbidite at volcanic contact	1949-69	937,117	31,836	CMH, 1979-1980; N.M.
Negus	Quartz veins in shear zones	1939-52	445,342	7,956	McGlynn, 1971, NMI Sheet
Lupin	Iron-formation hosted	1982-83	524,000	4,926	M.O.*
Cullaton	Iron-formation hosted	1981-83	167,000	2,059	M.O.
Tundra	Quartz vein at volcanic sediment contact	1964-68	170,281	3,251	CMH, 1979-1980
Salmita	Quartz vein in Yellowknife Supergroup	1983	29,200	740	M.O.
Ptarmigan	Quartz vein in turbidite	1941-42, 1983	33,323	404	
Shield Resources (Nose Gp.)		1967	1,043	16.2	North of 60, 1972
Thompson-Lundmark	Quartz vein in turbidite	1941-49	121,534	2,188	NMI Sheet
Camlaren	Quartz vein in turbidite	1962-63,	34,808	715	NMI Sheet
Outpost Islands	Polymetallic veins in sediments	1941-42	18,437	308	Lord, 1951
Ruth Mine	Quartz vein in turbidite	1942 &	652	17.1	NMI
DAF Gp., Gordon Lake	Quartz vein in turbidite	1947-48	278	8.4	NMI Sheet
Old Parr (Garskie)	Quartz vein in turbidite	1963-65, 1966-68	?, (some specimens sold) sold)	7.2	NMI SHeet
Rich prop. (Burwash Point)	Quartz vein in turbidite	1935	138	6	NMI Sheet
Norma Gp. (Beaulieu Yellowknife)	Quartz vein in turbidite	1947-48	419	1.5	NMI Sheet
Pensive Yellowknife	Quartz vein in turbidite	1939-?	?, Several	10.9	NMI Sheet
Tin (Star). Prosperous Lake	Quartz vein in turbidite	1950	27	0.8	NMI Sheet
June (JOON) Group	Quartz vein in turbidite	1977-78	Several hundred tonnes	9.3	Strike Lake officials
Rod Gp.	Shear in granodiorite	1978-79	11	0.5	K. Rasmussen
Hidden Lake	Quartz vein in turbidite	1968	Several hundred tonnes of 20 g/t	5.6	NMI
J.E.S./PAT	Quartz vein in turbidite	1938-39	180	1.1	NMI
BARKER Vein	Quartz vein in turbidite	1941 & 1948	?	10.3	NMI

TOTAL TONNES MILLED: about 19,225,000

TOTAL PRODUCTION: about 336,000 kg

AVERAGE GRADE: about 17.50 g Au/t (0.51 oz/ton)

*CMH = Canadian Mines Handbook
W.M. = Western Miner
M.O. = DIAND, Mines Overview

NMI = National Mineral Inventory Sheet
N.M. = Northern Miner

showings gold is found as flakes less than 1 mm in diameter ('flour gold'). Grades are low except within thin black sand layers, and recovery is difficult because of the fine grain size. The source of the gold has not been determined, but it may be the magmatic-hydrothermal deposits described previously. Exploration is by traditional panning or sluicing, but extreme care is required to avoid losses of the fine grains of gold. Given the low grade of the deposits, a large-scale operation would seem a requirement for profitable exploitation.

Aphebian Deposits

Early Aphebian paleoplacers are major contributors to the world's gold output and important targets in some parts of Canada (Tintor, N., 1983). There has only been one producer in Aphebian (lower Proterozoic) rocks in the NWT, although this may change in the near future if the Shear Lake Mine comes on stream. The Fox Mine (on one of the Outpost Islands) operated for a few years during the Second World War and produced copper, tungsten and nearly 308 kg of gold from ore averaging 17 g Au/t. The deposit is a stratiform body within a sequence of strongly crossbedded coarse-grained arkosic sandstone and quartz pebble beds. The mineralized bed is significantly finer grained than the enclosing rocks and contains considerable graphite and pyrite as well as chalcopyrite. As much as a decimeter of massive chalcopyrite was noted in trenches 1000 m northeast of the mine site. At this locale, the zone was in excess of 10 m wide, though most of it was very sparsely mineralized. Aside from the main zone, which can be traced intermittently on the Outpost Islands for 3000 m, a second copper-bearing zone lies 150 m to the east. It is not as strongly mineralized and has been found intermittently for 1500 m along strike. It is not clear whether these two zones consist of en-echelon lenses or form continuous zones. Lord (1951) reports the No. 1 zone has a maximum width of 2 m, but the mining width underground was less than 1 m.

Quartz veinlets with mica and andalusite were reported underground (Lord, 1951) and can be seen in surface exposures. Such veins are essentially confined to the mineralized bed of the "Shear Zone".

This association of gold, pyrite and chalcopyrite with scheelite, ferberite, magnetite, specular hematite, graphite and tin (probably cassiterite) is unusual. The general lack of signs of hydrothermal activity, together with the stratiform nature of the deposit, and association with a zone of fine-grained material in an otherwise coarse clastic suggest that a syngenetic (placer) origin for the gold, tin and tungsten seems most appropriate; possibly with an algal mat as a trap for heavy particles and as a source for the graphite. The sulphides may be partly sedimented and partly precipitated from solutions by decaying organic material.

QUARTZ VEINS

(1) Quartz veins in igneous rocks are present in a number of places in the Slave Province.

The most extensive quartz-vein gold deposits in igneous rocks are the "Arcadia" veins on the west side of the Anialik River Granite Gneiss. The gneiss is a biotite-bearing tonalite with extensive migmatitic areas and extensive crush zones around its borders. Gneissic layering is present in many parts of the body, but some areas are practically massive. Though a foliation of the minerals is apparent in most massive outcrops, the paucity of mafic minerals makes this difficult to measure. The gneiss is older (about 2695 Ga) than currently accepted ages for the enclosing supracrustals. If future geochronological work confirms this age relationship, then the granite gneiss must have been intruded as a plastic, relatively cool body.

Numerous pegmatites of varying relative age cut the gneiss, and a brick-red leuco-aplitic granite forms irregular veins and patches and as well forms extensive dykes along a set of north-northeasterly fractures. Refracturing along these dykes formed fissures in which quartz was deposited. Some such vein-dykes trend for many hundreds of meters and are 10 or more meters wide. Gold occurs sparingly in both quartz and aplite, and in places is sufficiently abundant to form shoots approaching mineable grade.

Vein formation, or at least the ground preparation for it, was accompanied by intense shearing that in places has caused a new gneissic layering to develop in the granite gneiss along and parallel to the vein walls.

Auriferous quartz veins or shear zones may be present in other granitic rocks in the Slave Province (some gold has been won from a shear zone in the Western Granodiorite complex on the ROD claims just north of the Yellowknife airport). Older gneissic granites are the most likely targets. There are numerous bodies of such rock in the Slave Province and it is unlikely that they have been carefully or intensely prospected.

Quartz veinlets (gash veins?) with gold have formed in a number of dioritic dykes in the Indin Lake area. The Colemac dyke deposit is the largest and best known. As the veins are small but abundant, the grade low, and some of the gold is in the dyke wall-rock of the quartz veins, selective mining or sorting would be difficult.

(2) Quartz veins in turbidites are common and widespread in the Slave Province, particularly in the Yellowknife Supracrustal Basin where nearly 150 showings of this type are known. Henderson and Fraser (1948, p. 270) show at least fifty sub-parallel veins on one 1000 m square island in Gordon Lake (Fig. 1). Only a small portion of these contain enough gold at the surface to be considered showings.

Little is known about the genesis of the auriferous quartz veins in turbidites, or their place in the complex structural history of the Slave Province. Clearly they are epigenetic deposits, and following theoretical work on shear zone deposits at Yellowknife (and elsewhere) they were probably formed by CO_2-chloride-rich hydrothermal solutions that were generated during regional metamorphism, or perhaps migmatization and anatexis of deeply buried suprarustal rocks or a basement substrate to the basin. Geophysical evidence suggests such rocks were sediments, perhaps similar to the Burwash Formation or the Octopus Formation (Helmstaedt and others, 1981).

Regional stratigraphic studies combined with detailed structural, sedimentological and geochemical studies are needed to analyze the environment of these quartz veins. Important questions are: Is there a lithological, geochemical or strata-related structural control, or is the control strictly one of competent beds providing 'openings' or low-pressure zones for vein deposition? As yet there is no clear understanding even of the spatial relationship of

*TABLE III: GOLD SHOWINGS IN THE NWT BY NTS & TYPE OR ASSOCIATION**

A. KEEWATIN *(62)* ARCHEAN SHOWINGS *(mainly)*

NTS	Total Showings	TYPE OF SHOWING						
		Not Specified	Iron Formation	(Sheared?) Volcanics	In Cong. & Qzite	In Intrusive Dykes	Quartz Veins in	
							Volcs.	Seds.
55	16	3	-	8	-	-	4	1
56	1	1	-	-	-	-	-	-
65*	45	5	16	9	6	2	4	3

* Includes 17 showings in the Cullaton Lake-Kognak River Area mainly in the Hurwitz Group

B. SLAVE STRUCTURAL PROVINCE *(426 showings)*

NTS	Total Showings	GENETIC TYPE OR ASSOCIATION									
			With Quartz Veins				Shears				
		Not Specified	In Intrusive Dykes	In Plutonics	In Volcanics	In Greywacke Turbidites	In Volcanics	In Sediments	In Plutonics	Rusty Zone	In Amphibolite
75	4	1	1	-	1	1	-	-	-	-	-
76/B	11	-	6	-	2	3	-	-	-	-	-
76/D	21	1	-	-	9	3	6	2	-	-	-
76/E	43	-	-	-	-	-	-	-	-	-	43
76/G,L,N	20	-	1	-	-	3	-	1	-	2	13
76/M	23	-	-	20	1	1	1	-	-	-	-
76/O	14	-	-	-	9	-	5	-	-	-	-
77	9	1	-	-	5	-	2	-	1	-	-
85/I	101	-	2	1	1	91	4	1	1	-	-
85/J	50	2	3	-	10	8	22	2	2	-	1
85/N	5	-	-	-	-	3	-	1	-	-	1
85/O	17	-	2	-	2	4	1	5	-	-	3
85/P	39	-	-	2	8	26	1	-	-	-	2
86/B	54	-	3	1	23	16	8	1	-	-	2
86/H	15	-	-	-	-	-	2	-	-	-	13
TOTALS	426	5	18	24	71	159	52	13	4	2	78

C. BEAR PROVINCE (7 showings)

85/H	2	-	-	-	-	2	-	-	-	-	-
86/H	3	-	-	-	-	-	1	-	1	1	-
86/K	2	-	-	-	-	2	-	-	-	-	-

D. CORDILLERAN STRUCTURAL PROVINCE (14 showings)

	Placers	Skarn
95/B	2	-
95/E	7	-
95/J	1	-
105	-	4

such veins to intrusive bodies or to the metamorphic isograds identified in the Yellowknife Basin.

Some quartz veins eg. Camlaren, are essentially stratabound, but without extensive mapping and good exposure this may be obvious only if the vein (as with the 'Hump Vein' at Camlaren) is essentially confined to the nose of a fold. The 'Hump' was practically confined to the nose of a steeply plunging fold, (Henderson and Fraser, 1948, p. 271) and was little different on the 1000 foot level than it was at the surface. Graphite was abundant in the lower levels of the mine, coating fold hinges and forming a parting between the quartz vein and wall rock. Narrow extensions of the main quartz mass extended along the fold limbs, and were associated with extensive shearing, which suggests faulting accompanied folding.

Quartz veins in turbidites are typically thin and erratically mineralized. Grades in the order of 30 g Au/t are typical of ore sections, though some are much richer. Such grades are necessary to make these meter-wide (or narrower) veins mineable. None of the examples developed up to now have a tonnage potential in excess of 100,000 tonnes; thus the profitability of such deposits is limited considering present-day capital and labour charges.

Not all quartz deposits in turbidites are simple veins. A number are described as quartz stockworks and irregular discontinuous veins and quartz lenses in shear zones. Perhaps these have a different genesis and history than the simple quartz veins, some of which resemble 'saddle reefs'. But few veins are unaccompanied by shearing, as might be expected in view of the extensive repeated deformations that have affected the turbidite basins (Fyson, 1975, 1981, 1982).

Quartz stockworks and shear zones may have greater tonnage potential than simple quartz veins,

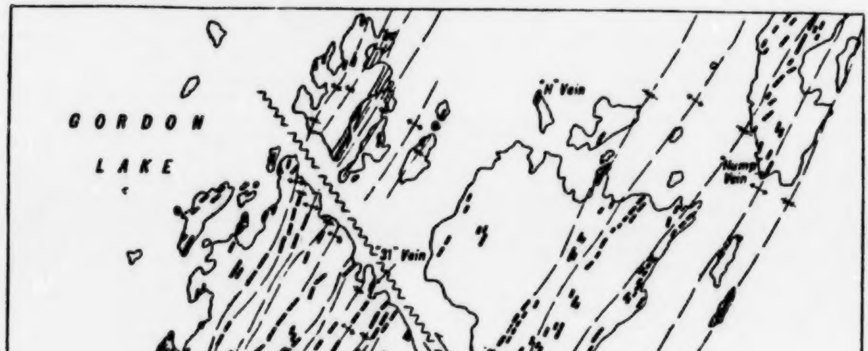

FIGURE 1: Zenith Island in Gordon Lake, showing relation of vein quartz to structure of sediments. The Hump Vein at upper right was site of the Camlaren Mine. Other high-grade veins, the H and 31 Veins, are also shown. (from Henderson and Fraser, 1948)

but data on them are remarkably scanty, perhaps because few had grades high enough to hold the attention of the prospectors of earlier years, when 15 g Au/t or better was deemed necessary for profitability. A recently obtained drill intersection in a quartz-carbonate shear zone found in the Gordon Lake area ran 8 g Au/t across slightly more than 15 m; within this was a wide section of 3 times this average grade.

Quartz veins are amazingly abundant on Zenith and nearby islands near Camlaren Mine in Gordon Lake. Henderson and Fraser (1948) show over 50 probably separate veins (Fig. 1) on Zenith Island alone. It is not clear from their diagram how wide the veins are, nor what percent by volume of the rock mass they would make up, though the relations of the veins to fold axes (hinges) are made clear by Henderson and Fraser on page 269, "beds along the axes of the fold generally meet to form a sharp V, and at the point of the V, or axial part of the fold, the beds are commonly ruptured. Minor faulting movements along the broken crests of the folds in many cases result in well-defined shear zones. Discontinuous quartz veins and irregular lens-like masses of quartz lying more of less parallel with the bedding are plentiful throughout the sediments, but tend to be concentrated along the ruptured and sheared, anticlinal and synclinal fold axes (Fig. 1)."

Such a profusion of quartz veins might be termed a mega-stockwork! Since little information is available on the size of these veins or their gold content, estimates of grade for the approximately 750 x 1400 m western half of Zenith Island (which appears to have a higher incidence of veins than the east side) is not possible, however at approximatly 2.7 specific gravity for a greywacke/quartz vein mixture, dominantly greywacke, 2.8 million tonnes of rock per meter of depth is available. Tonnages in the 100's of millions are available in the Zenith Island area. Open-pit mining costs for such tonnages could make 20 dollar rock (about 1.5 g Au/t) ore!

A few 300-meter HQ or BQ-size drill holes should give a reasonable assessment of the grade of a large block of this ground. Detailed geological mapping to permit a better estimate of the volume of vein material would be a logical first step.

(3) Quartz veins at volcanic-sediment contacts tend to be considerably larger than veins in turbidite sediments. Veins at Tundra and Discovery are closely associated with pyrrhotite-rich sulphide iron-formation which may be a source rock. Exposure is much better in the Discovery area than in the Tundra-Salmita area. South of Discovery there are a number of siliceous (cherty?) sulphide-bearing zones that contain sulphides and gold. Perusal of Wichwar's (1957) paper on Discovery, in the light of more recent concepts on ore deposit genesis, suggests the deposit formed through processes of metamorphic concentration of quartz and gold within strata that contained an abundant exhalative component - cherts and sulphides. Pyrrhotite iron-formation outcrops within a stone's throw of the Discovery shaft.

Thus the deposits in the Discovery area (and probably others like them) are stratabound, and this is an important exploration guide! Another conclusion is that potential for mineable gold deposits probably exists in the exhalite-rich zones as well as in the quartz veins themselves, and this potential may be at least as important as that of the quartz veins.

Exploration of such targets would include detailed geophysical and geochemical surveys to differentiate and then evaluate favourable strata.

SHEAR ZONE DEPOSITS

Quartz-chlorite-sericite shear zones in basaltic volcanics have been the most productive gold deposits mined so far in the NWT. Shear zones in sediments have been discussed briefly (see Shear Lake Zone and shear zones in turbidites above) and will not be discussed further except to point out that most 'shear zones' in sediments so far described do not have the intensity of alteration or variety of silicate sulphide and sulphosalt minerals that are found in volcanic-hosted examples.

Shear zone ore bodies are, according to recent research, formed by metamorphic dewatering and perhaps hydrothermal pumping of ore-forming fluids apparently generated from deeply buried parts of the volcanic belt and perhaps a substrate of pre-existing rocks (basement or sediments).

Various techniques have been used to explore for shear zone deposits. The chloritic-sericitic nature of these zones makes them susceptible to erosion and few are well exposed. Only traces of the Giant shear zones, and none of the Campbell shear zone, are exposed. Careful prospecting and intuition are needed to find evidence of such zones and then infer their location from mineralogy, texture and geochemistry. Under ideal conditions, IP surveys should identify shear zones because of their disseminated sulphides, however in much of the southern Slave Province valleys are floored with clay and silt containing 30% to 50% ice lenses. It is doubtful if many geophysical techniques can penetrate such overburden. Geological mapping (particularly mapping of the intensity of shearing) and rock geochemical techniques have been used in the northern part of the Yellowknife Volcanic Belt, but mineable deposits have not been found. Nevertheless such techniques together with prospecting and soil- or bio-geochemistry seem the most applicable methods.

Favourable areas include the margins of the Yellowknife Supracrustal Basin, particularly the southern part of the Yellowknife Volcanic Belt. Unfortunately 99% of this part of the belt is underwater so that, failing a geophysical signature, core drilling may be the only useful tool to test for auriferous shear zones.

The Beaulieu-Cameron River volcanic belt contains a number of gold showings. The eastern limb of this huge volcanic belt is cut by a large shear zone that trends northerly from just north of Turnback Lake to beyond Beniah Lake. Much of this area has received little attention of late, though there was extensive base metal prospecting there in the late 60's and early 70's. Gold showings are abundant in the volcanics of the Cameron River portion of this belt and in the turbidites immediately to the west (Gordon Lake area).

IRON-FORMATION-HOSTED DEPOSITS

Turbidite-iron-formation-hosted sedimentary exhalative deposits are at present the most exciting targets in the NWT because two of the territories' newest and largest gold mines produce from such deposits.

The Lupin Mine is a medium-grade deposit circa 13.6 g/t in amphibolitic iron-formation thought to have formed in sub-basins of a deep-water turbidite basin. Gibbins (1981) described the deposits as:

> "a 30 to 50 foot-wide lens of silicate-sulfide facies iron formation that has been metamorphosed to garnet-grunerite amphibolite and deformed into a large, steeply-plunging fold."

He described the rocks as varying:

> "from fine- to coarse-grained, schistose to massive, black to light green, contain nil to greater than 80 per cent almandine garnet (Pl. II E), nil to greater than 80 per cent sulphide (Pl. II F) and include sugary-textured quartz bands or "quartzite" (believed to have originally been chert), chlorite and mica schist and several varieties of amphibolite or silicate facies iron-formation. Minor amounts of pyrite, chalcopyrite and magnetite occur with the sulfide facies iron formation. Carbonate minerals are not found at Contwoyto Lake".

Underground exposures of high-grade ore, which contain small but visible grains of gold, are finely layered alternations of dominantly pyrrhotite and dominantly silicate rock suggestive of sedimentary deposition. Large diamonds and lathes of arsenopyrite have overgrown the sedimentary layering and the sub-parallel metamorphic foliation and occur mainly along the borders of crosscutting (tension-gash filling?) quartz veins.

Soft-sediment deformation and later folding have increased the width of the Lupin deposit, and metamorphic segregation into quartz veins seems to be confined to the mineralized bed. Probably little gold was lost by metamorphism, in fact, the gold in quartz veins could have been introduced from leaner portions of the zone.

The B-Zone gold deposit at Cullaton Lake is remarkably similar in setting (turbidite-hosted sulphide iron-formation) and appearance of ore (alternating thin layers of varying pyrrhotite content) to the Lupin deposit.

Page (1981) describes the ore body as having:

> "a close affinity with the sulphide facies iron-formation which is found within or bordering the oxide facies and ranges in thickness from 2 to 57 feet (0.61 to 17.4 meters).
>
> The sulphide facies contains dominantly the sulphides pyrrhotite and pyrite, with lesser amounts of arsenopyrite and chalcopyrite.
>
> Magnetite, siderite and a group of iron silicates make up the remainder ... combining with the sulphides to form iron-rich units that are crudely banded with chert.
> The most abundant primary iron sulphide is pyrrhotite, which contributes approximately 60-70% of the sulphide mode. Pyrite is second in abundance, occurring both as a primary mineral, as well as replacing pyrrhotite. Arsenopyrite is least abundant with chalcopyrite forming an accessory mineral."

Mineralogical differences include the presence of carbonates at Cullaton versus the absence at Lupin, and the large metamorphic arsenopyrite crystals at Lupin. The Cullaton iron-formation is more 'developed' than Lupin's, consisting in the former case of four distinct facies: carbonate, silicate oxide and sulphide, but in the latter of a combined silicate-sulphide facies.

The setting within a sequence of volcanics overlain by greywackes is similar, but the Cullaton Lake deposit seems to be closer to the basin margin, whereas the Lupin deposit probably formed in an abyssal plain.

Exploration methods for both varieties of deposit are similar. Exploration for iron-formation-hosted gold deposits can begin with aeromagnetic maps, as most if not all such deposits will be anomalously magnetic. Sharply folded magnetic trends are primary targets, sampling and assaying of any "sedimentary" amphibolites should suffice to distinguish favourable units, though in areas of thick glacial debris geochemistry and boulder assaying may be required.

Gold showings in turbidite amphibolitic iron-formation have been found from Itchen Lake area, (86H) to the east across the Contwoyto Lake area (76E)to the Back River (76B,G) and also farther north in 76N and 76 O. Similar deposits could exist within the rocks along the Thelon Front in the Duggan and Overby Lake areas where higher-grade metamorphism may have increased the grain size of the deposits, which might decrease the cost of recovery.

Large areas have been staked in the Itchen, Contwoyto and Reagan Lakes area for turbidite iron-formation deposits. Additional favourable ground is available west of Bathurst Inlet. Large areas of migmatized "Yellowknife Supergroup" around the borders of the turbidite basins deserve some attention as parts of them were probably derived from turbidites, and iron-formation within these rock would be only modified by metamorphism.

CONCLUSIONS: WHERE TO EXPLORE FOR (PROFITABLE) GOLD DEPOSITS IN NWT

Based on size and grade of current and past producers, mafic (basaltic) volcanic belts are the most favourable targets for finding large mineable-grade gold deposits. These deposits will be in shear zones or in quartz veins near the volcanic-sedimentary contact where, experience suggests, such veins will be associated with sulphide iron-formation.

Favourable areas not presently being intensely explored include the Beaulieu River, Camsell Lake. Indian Mountain Lake and Point Lake volcanic belts in the south and west side of the Slave Province and volcanic remnants in the Thelon-Front Zone.

Prospecting, regional and detailed geology are primary tools for shear zone location; geophysical techniques, detailed geological mapping and geochemistry, and finally extensive drilling are required to test any favourable zones.

Exploration for amphibolitic iron-formation has been concentrated across the centre of the Slave Province because most amphibolite showings have been found in this area. Parts of the Kaminak Volcanic Belt are also favourable for such deposits, particularly the Cullaton-Kognak area.

Aeromagnetic mapping of turbidite basins is probably the best 1st-order exploration tool. Formational magnetic highs warrant investigation, particularly those that appear to be tightly folded. Ground magnetometer mapping, can be rapid and effective in tracing favourable zones. Trenching and drilling, of course, are required as with most other gold situations.

There may be useful exploration guides to be found in the stratigraphy and sedimentaton within turbidite successions, but work in this area has only recently begun. Perhaps rock geochemistry will provide criteria that can be used quickly and cheaply to differentiate between barren and auriferous sub basins.

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QUALITY

ORIGINAL